

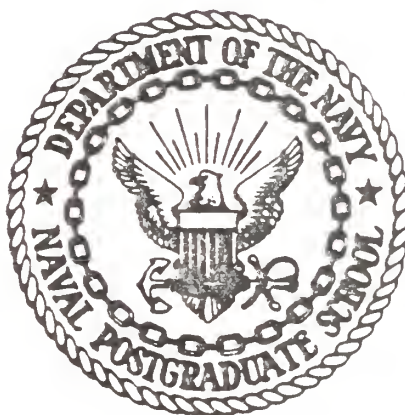
PRODUCTIVITY MEASUREMENT AND ENHANCEMENT
ON U. S. NAVY SHIPS

Richard Cox Felsing

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THESIS

PRODUCTIVITY MEASUREMENT AND ENHANCEMENT
ON U. S. NAVY SHIPS

by

Richard Cox Felsinger

September 1976

Thesis Advisor:

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Productivity Measurement and Enhancement
on U. S. Navy Ships

by

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Lieutenant Commander, United States Navy
A.B., University of Delaware, 1966

Submitted in partial fulfillment of the
requirements for the degree of

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from the
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September 1976

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The purpose of this research project is to examine the problem of how to measure and enhance productivity on U. S. Navy ships. Productivity measurement and enhancement is discussed in terms of analytic models, benefits and costs, factors affecting productivity, and output and input measures. A study was conducted with 26 U. S. Navy ships in which it was found that (1) the average number of men assigned was significantly more important than the amount of OPTAR consumed for repair parts in affecting the number of planned maintenance actions accomplished, (2) labor and material productivity ratios could be computed with PMS (maintenance), personnel, and OPTAR cost data, (3) ships with high labor productivity ratios tended to have high PMS accomplishment rates, and (4) four factors related to the level of productivity were adequacy of tools, adequacy of supplies, extent of teamwork, and adequacy of planning. A shipboard productivity improvement program including a ship efficiency questionnaire and a computer-based ship productivity report are presented.

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I. INTRODUCTION

Productivity or efficiency is the relationship between an organization's output to its input. The terms productivity and efficiency are synonymous. Improving productivity is an objective endorsed by nearly every commander and commanding officer in the United States Navy. The following are statements made by high-ranking civilians and officers in the United States Navy relating to productivity. On 18 March 1975 the Honorable J. William Middendorf, II, Secretary of the Navy, stated before the United States House of Representatives Appropriations Committee, "Achieving maximum force readiness within the manpower resources and budget constraints directed by Congress is our goal."¹ Before the same committee on the same day Admiral James L. Holloway, United States Navy, Chief of Naval Operations stated, "Our most important challenge is that of maximizing our readiness to meet the Navy's undiminished force levels.....I am emphasizing that our attention and energies must be focused on maximum readiness within the limits of resources available to us."²

¹Ninety Fourth Congress, Department of Defense Appropriations for 1976, Hearings before a Subcommittee on Appropriations House of Representatives, 1976.

²Ibid.

Admiral Cousins, Commander-in-Chief, United States Atlantic Fleet in January 1975 stated,

"Most Atlantic Fleet personnel are working hard with commitment and dedication to our Navy. However, a combination of attitudes and misconceptions appears to be limiting the productive work of some of our people. There are cases in which fleet personnel are simply not being required to support a reasonable working day. In other instances time spent on the job is inefficiently used, largely because of inadequate management. Such waste of valuable manpower could not be afforded in business or industry and is unacceptable in the Navy. We cannot be satisfied until we are getting the full potential from everyone in the Atlantic Fleet - the full potential in leadership and a full day's work from all hands."³

These statements indicate the importance of productivity on U. S. Navy ships. The basic purpose of this research has been to examine the problem of "how to measure and enhance productivity on U. S. Navy ships." In the author's opinion there are three stages of productivity measurement and enhancement in organizations like U. S. Navy ships. These represent three levels of managerial sophistication. The levels are:

- Level I - Productivity improvement is vitally needed in our organization.
- Level II - Productivity improvement is vitally needed in our organization. We are implementing these "x" actions to improve our productivity.
- Level III - Productivity improvement is vitally needed in our organization. We are implementing these "x" actions

³Statement made in regards to CINCLANTFLT objective for improved work productivity.

to improve our productivity. We are monitoring these productivity measures to determine if these actions are improving our productivity.

In this author's opinion 95 per cent of all officers and petty officers on U. S. Navy ships are at Level I. Productivity improvement on U. S. Navy ships receives "much talk but little action and very little measurement."

In the author's opinion productivity measurement and enhancement is important on U. S. Navy ships for the following reasons:

- the increasing interest of Congress and the American people that all government organizations produce a maximum of services for each tax dollar collected,
- the increasing cost of personnel and materials on U. S. Navy ships,
- the increasing scarcity of certain materials, such as special lubricants, special alloy repair parts, etc.,
- the increasing sophistication of naval weapons systems and the greater need for skilled maintenance on them,
- attitudes of personnel on U. S. Navy ships which frequently are oriented towards increasing the input of resources vice maximizing the output of services,
- the lack of a means to quantitatively support subjective judgments on the following:
 - the degree of efficiency with which an officer or petty officer uses his resources (men and material),

- the determination of the optimum allocation of resources among departments and work centers on U. S. Navy ships,

- the determination of when a department or work center requires more resources to accomplish a given mission.

There are five major purposes of this study:

(1) To present a usable productivity measurement and enhancement program for U. S. Navy ships. The program is presented in Appendix A. The program is the end product of this research. It is considered the major contribution of this research.

(2) To present a usable attitude survey questionnaire which measures key attitudes and perceptions of enlisted personnel which affect productivity. The questionnaire is presented in Appendix A. The analysis of the 2212 responses is contained in Appendix B.

(3) To present quantitative data to support the opinion that a productivity measurement and enhancement program is both feasible and desirable on U. S. Navy ships.

(4) To present an overview of current U. S. Government and Department of Defense efforts in productivity measurement and enhancement which could support U. S. Navy efforts in productivity measurement and enhancement. Research, program implementation, publications, training requirements, and measurement activities are discussed.

(5) To present a list of recommendations which could improve productivity measurement and enhancement efforts on U. S. Navy ships.

A. OBJECTIVES AND EXPERIMENTAL PROCEDURES

As stated earlier, the major objective of this research was to examine the problem of "how to measure and enhance productivity on U. S. Navy ships." The problem was examined from a management point of view vice an engineering point of view. There were 11 specific objectives of the research.

(1) Review past and current research on productivity measurement and enhancement on U. S. Navy ships.

(2) Review existing and planned productivity measurement and enhancement programs in the U. S. Federal Government, the Department of Defense, and the Department of the Navy.

(3) Review and develop analytic models to explain productivity concepts.

(4) Examine factors affecting productivity on U. S. Navy ships.

(5) Formulate output, input, and productivity measures for U. S. Navy ships.

(6) Measure productivity on 26 U. S. Navy ships participating in the U. S. Navy Pacific Fleet Equipment Maintenance and Related Maintenance (EMRM) Project during the time period 1 November 1975 to 30 April 1976.

(7) Evaluate the productivity measures computed on the 26 U. S. Navy ships to estimate their degree of validity, accuracy, and usefulness.

(8) Develop and administer an attitude survey questionnaire for enlisted personnel on the 26 U. S. Navy ships. The purpose of the survey was to ascertain attitudes and perceptions of shipboard personnel regarding factors affecting productivity.

(9) Develop a usable productivity measurement and enhancement program for U. S. Navy ships.

(10) Develop a usable automated (computer-based) ship productivity report for general use for U. S. Navy ships.

(11) Develop a set of recommendations which could improve productivity measurement and enhancement efforts on U. S. Navy ships.

The experimental procedures in this research included methods and techniques from microeconomics, organizational development and statistics. Microeconomic concepts were used for the following:

- calculation of production functions using the number of planned maintenance actions accomplished as the output measure,

- calculation of average and marginal productivity ratios using maintenance, personnel, and OPTAR cost data,⁴

- calculation of elasticity coefficients to determine the effect of personnel and repair part expenditures on the number of planned maintenance actions accomplished.

⁴OPTAR costs are expenditures approved by the ship's commanding officer for day-to-day equipage, repair part, and other operating expenses. They do not include fuel, utilities, major shipyard repairs, or personnel expenses.

Methods of Organizational Development were used for two major purposes. The first was to design the attitude survey questionnaire. The second was to explain effects of gathering and disseminating productivity information. The theory of cognitive dissonance was used to explain this effect.

Statistical methods and procedures were used throughout this research. Specifically the following methods were used:

- descriptive statistics to display means, medians, standard deviations, etc. of data collected,

- hypothesis testing using both parametric and non-parametric tests to determine differences between high and low productivity ships,

- correlation analysis to determine the strength of relationships of factors affecting productivity measures,

- simple and multiple linear regression to develop models to predict output measures with input measures, to predict productivity measures with attitude survey results, and to predict effectiveness measures such as PMS⁵ accomplishment rates with attitude survey results,

- factor analysis to determine underlying dimensions measured by the attitude survey questionnaire.

The majority of the statistical analysis was done using the Statistical Package for the Social Sciences (SPSS) computer subroutines on the Naval Postgraduate School IBM 360/65

⁵PMS is the U. S. Navy Planned Maintenance System which is the maintenance system used on U. S. Navy ships. The PMS accomplishment rate is the ratio of MR's (Maintenance Requirements) accomplished to MR's scheduled.

computer. Some analysis was done using the Biomedical Computer Programs (BMD P Series). The maintenance data was summarized using computer programs written in ANSI COBOL (American National Standards Institute Common Business Oriented Language).

II. BACKGROUND

A. SURVEY OF LITERATURE: PAST AND CURRENT RESEARCH ON PRODUCTIVITY MEASUREMENT AND ENHANCEMENT ON U. S. NAVY SHIPS

In conjunction with this research project a literature search was conducted on the subject of productivity measurement and enhancement on U. S. Navy ships. The formal search was conducted through the U. S. Naval Postgraduate School Library, Monterey, California 93940, the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314, and the Defense Logistics Studies Information Exchange (DLSIE), U. S. Army Logistics Management Center, Fort Lee, Virginia 23801.

It was found that there were no reports or research directly addressing the subject of productivity measurement and enhancement on U. S. Navy ships.

Numerous reports and studies were found that indirectly addressed productivity on U. S. Navy ships. These reports were classified in the following subject categories: management, maintenance, training, manpower, management information systems, resource allocation, costs, systems analysis, manpower requirements, work analysis, material condition, ship overhaul, work measurement, production, planned maintenance system, repairs, supply support, operations analysis, performance analysis, leadership, attitude measurement, output measurement, economic analysis, motivation, cost reduction,

methods improvement, performance evaluation, organizational development, Human Resources Management Program, information systems, data systems, command and control, etc.

Additionally, an informal literature search was conducted by telephone to numerous Department of Defense and Department of the Navy organizations to ascertain if they had sponsored or conducted any recent research on the subject of productivity measurement and enhancement on U. S. Navy ships. The following organizations were informally contacted: Navy Manpower and Material Analysis Center Atlantic, Navy Manpower and Material Analysis Center Pacific, Center for Naval Analyses, Office of Naval Research, Office of the Chief of Naval Operations (OP-01, OP-03, OP-04, and OP-92), Office of the Comptroller of the Navy, Office of the Chief of Naval Material, Office of the Commander Naval Sea Systems Command, Office of the Assistant Secretary of the Navy for Financial Management, and the Office of the Assistant Secretary of Defense for Installations and Logistics. The informal search found numerous reports and studies indirectly related to the subject but none directly relating to the subject of productivity measurement and enhancement on U. S. Navy ships.

There are four major studies on shipboard maintenance that were used for background material for this research. These studies addressed the problem of how to improve maintenance on U. S. Navy ships. They discussed maintenance problems, management concerns regarding maintenance, and factors affecting the level of maintenance accomplishment on U. S. ships. These four studies were:

- (1) Production by Ship's Force During Overhaul, Report #82, Navy Manpower and Material Analysis Center, Atlantic, Norfolk, Virginia 23511, January 1973,
- (2) Improvement of Planned Maintenance Accomplishment within the Pacific Fleet, Report #138, Navy Manpower and Material Analysis Center, Pacific, San Diego, California 92132, August 1974,
- (3) Improvement of Planned Maintenance Accomplishment within the U. S. Pacific Fleet (Phase II), Report #138A, Navy Manpower and Material Analysis Center, Pacific, San Diego, California 92132, March 1975,
- (4) Maintenance Personnel Effectiveness in the Navy, Professional Paper #143, Center for Naval Analyses, 1401 Wilson Boulevard, Arlington, Virginia 22209, January 1976.

In FY 1976 the Equipment Maintenance and Related Maintenance (EMRM) Project was conducted in the U. S. Atlantic and Pacific Fleets. The project investigated the impact of increased funding for repair parts on maintenance accomplishment. The project involved nearly 100 U. S. Navy ships in both fleets. The EMRM Project in the U. S. Navy Pacific Fleet was the major source of data for this research on productivity measurement and enhancement on U. S. Navy ships.

B. PRODUCTIVITY MEASUREMENT AND ENHANCEMENT PROGRAMS IN THE U. S. FEDERAL GOVERNMENT

1. Federal Agencies

There are numerous agencies and programs in the U. S. Federal Government which have responsibilities in productivity

management and enhancement.⁶ Some of these agencies are oriented toward improving productivity in the economy, in industries, in industrial organizations, in state and local government organizations, and in other profit and non-profit organizations. Other of these agencies are oriented toward improving productivity in U. S. Federal Government as part of the Federal Productivity Program.

These agencies represent an excellent resource for assistance, training, and information for individuals and organizations interested in productivity measurement and enhancement in their organization. Appendices D through I list some of the publications, instructions, services, and research activities of these agencies. Appendix D lists various publications on productivity available from government agencies. Appendix E contains sample newsletters and bulletins on productivity available from federal agencies. Appendix F shows examples of training courses and seminars available from federal agencies. Appendix G shows an example of the research being conducted on productivity by the National Science Foundation. Appendix H is a policy statement regarding the Federal Productivity Program. Appendix I contains excerpts from the Annual Report to the President and the Congress on Productivity Programs in the Federal

⁶The majority of the information in this chapter concerning federal agencies and federal programs was gathered from verbal statements and handout material presented at the Productivity Through Measurement Seminar held on 23 June 1976 in Washington, D. C. The seminar was sponsored by the National Center for Productivity and Quality of Working Life. Permission was received to reprint all in the Appendices.

Government FY 1974. These appendices are included in this report to show the wide breadth of activity in the U. S. Federal Government oriented towards productivity improvement and to list government sources for further information on productivity measurement and enhancement.

The three major U. S. Federal Government agencies which have responsibilities for productivity measurement and enhancement in the United States as a whole are the National Center for Productivity and Quality of Working Life, the Bureau of Labor Statistics within the Department of Labor, and the U. S. Department of Commerce. The National Center was authorized on 28 November 1975 by the 94th Congress. It affirmed the government's commitment to a long-range program to promote continued productivity growth. The National Center's enabling legislation (Public Law 94-136) enunciated a national policy to "encourage productivity growth consistent with the needs of the economy, the natural environment, the needs, rights, and best interests of management, the work force, and consumers." The National Center's purpose is to stimulate national efforts consistent with this policy. The National Center has been active in publishing productivity manuals and reports and conducting productivity seminars. The National Center grew out of the National Commission on Productivity and Work Quality composed of leading business, labor, government, and public representatives. The National Commission was headed by Vice President Nelson Rockefeller.

Within the U. S. Department of Labor, the Office of Productivity and Technology of the Bureau of Labor Statistics

is responsible for compiling productivity statistics and publishing productivity reports. These reports cover all sectors of the U. S. economy including the U. S. Federal Government. The Office of Productivity and Technology has responsibility for four major research programs. The productivity research program provides comprehensive statistics for the U. S. economy and its major component sectors and individual industries. The technological studies program investigates trends in technology and their impact on manpower and productivity. The international labor statistics program compiles and analyzes statistics on trends in productivity and related factors in foreign countries. The construction labor requirements program deals with the construction industry.

Within the U. S. Department of Commerce, the Domestic and International Business Administration, Bureau of Domestic Commerce, Office of the Ombudsman for Business publishes the Productivity Series Bulletin shown in Appendix D, productivity reports, and productivity articles. Additionally, within the Department of Commerce several organizations carry on activities related to productivity. Two such organizations are the Economic Development Administration (EDA) and the National Bureau of Standards.

2. The Federal Productivity Program

There are many federal agencies which have responsibilities to oversee, monitor, or provide assistance for productivity measurement and enhancement programs within the U. S. Federal Government. These agencies include the Office

of Management and Budget, the General Accounting Office, the General Services Administration, the Joint Financial Management Improvement Program, the Bureau of Labor Statistics, and the Civil Service Commission.

Each of these agencies has specific responsibilities. The Office of Management and Budget has overall responsibility for the Federal Productivity Program. The General Services Administration provides technical guidance in developing and using work measurement and productivity measurement systems. It assists agencies in developing productivity improvement programs with respect to procedures improvements and mechanization projects. The Civil Service Commission provides policy guidance and technical assistance to agencies on the personnel management aspect of productivity. This includes manpower planning and utilization, training, executive development, labor relations, pay and incentives, job design, personnel management research, and the integration of these functions with overall productivity improvement programs.

The Joint Financial Management Improvement Program (JFMIP) is a joint and cooperative undertaking of the Office of Management and Budget, the General Services Administration, and the Civil Service Commission. The overall objective of JFMIP is to improve and coordinate financial management policies and practices throughout the government so that they will contribute significantly to the effective and efficient planning and operation of government programs. Specifically, JFMIP has the responsibility, with the assistance of the Bureau of Labor Statistics, to analyze the factors which have

caused productivity changes and prepare an annual report on productivity programs in the Federal Government. JFMIP seeks opportunities to expand the coverage of productivity indices and to improve the representativeness of the measures.

The JFMIP Annual Report to the President and the Congress on Productivity Programs in the Federal Government FY 1974 of June 1975 is a comprehensive document summarizing productivity programs and productivity trends in the U. S. Federal Government.

This annual report indicated that productivity measurement data was collected on over two million workers engaged in federally funded activities. In FY 74 data was collected on approximately 65 per cent of the Federal civilian work force. In the Department of Defense 361,500 staff-years were measured out of a total of 1,039,900 staff-years (34.8 per cent). The report cited that productivity gains were most often tied to use of capital equipment, automation, work simplification, reorganization, revised procedures and work flow, and technological improvement.

The annual report set forth general guidelines for federal agency productivity improvement programs. The seven basic ingredients include:

- (1) Commitment - both real and visible support from top management.
- (2) Involvement - by personnel at all levels of the organization in productivity planning and analysis.
- (3) Incentives - opportunities for individual benefit from accomplishing productivity improvement.

- (4) Goals and objectives - should be defined for the organization in terms of output products.
- (5) Analytical capability - to analyze data and situations, identify alternatives, and recommend changes.
- (6) Measurement and reporting systems - should be systematic methods of collecting, analyzing, and reporting productivity data along with other measures of effectiveness and work quality.
- (7) Evaluation - should be provisions for independent reviews and audits.

The annual report cited many lessons and recommendations for future actions regarding measuring and enhancing Federal productivity. Important lessons learned include:

- (1) Productivity data represents a powerful management tool but must be used in conjunction with other measures of performance.
- (2) Some types of work, such as research, cannot at present be measured using conventional productivity techniques.
- (3) Innovative approaches to total performance measurement are needed.
- (4) Caution should be exercised when making comparisons of productivity indexes, even for similar functions.
- (5) In analyzing productivity data, long-term trends are more significant than short-term changes.
- (6) Improvements are needed in the analysis of reasons for productivity increases and decreases.
- (7) Productivity improvements or declines do not just happen but result from specific actions. Identification and

analysis of such actions are the real payoff from productivity measurement. Without identification and analysis, measurement is meaningless.

For the future the following are four major objectives for the Federal Government:

- (1) Expand and improve coverage of productivity and performance measurement systems.
- (2) Strengthen productivity improvements throughout the government.
- (3) Improve interchange of productivity ideas.
- (4) Respond to the national need to improve productivity focusing on manufacturing technology, capital acquisition, motivation and work quality, measurement technology, and government regulations.

In the Department of Defense the guidelines and reporting instructions for the JFMIP are being implemented through DOD INST 5010.34 of 4 August 1975 entitled "Productivity Enhancement and Evaluation, Operating Guidelines and Reporting Instructions." This instruction covers the DOD Productivity Program and encompasses many previously implemented programs such as Standardization of Work Measurement, DIMES, and Economic Analysis. The Assistant Secretary of Defense for Installations and Logistics has the overall responsibility for the DOD Productivity Program. Goals for the DOD program include increasing the percentage of the DOD civilian force covered by productivity measurements and to increase productivity 1.5 per cent annually. The Defense Supply Agency's

Performance Reporting System is one of the most comprehensive and functional productivity measurement systems in the Department of Defense.

In the Department of the Navy the Assistant Secretary of the Navy for Financial Management has overall responsibility to implement the Department of the Navy Productivity Program in accordance with DOD Instruction 5010.34 of 4 August 1975. Personnel in Office of the Comptroller of the Navy and in the Office of the Chief of Naval Operations (OP-92) have specific responsibilities for this program. The Department of Navy Productivity Program is oriented towards the support forces vice the operating forces of the U. S. Navy. The Naval Supply Systems Command's Activity Management Report (AMR) is one of the most comprehensive and functional productivity measurement programs in the U. S. Navy. It covers the Naval Supply Centers and Fleet Material Support Offices in the Naval Supply Systems Command. The AMR is an automated report which is used principally to detect problem areas, to reallocate resources, and to support budget decisions.

III. THE PROBLEM

The problem of productivity measurement and enhancement on U. S. Navy ships will be discussed in terms of concepts of productivity analysis, factors affecting productivity, benefits and costs of a productivity measurement and enhancement program, and the formulation of productivity measures for U. S. Navy ships.

A. CONCEPTS OF PRODUCTIVITY ANALYSIS

There are many analytic frameworks or models which could be used to describe productivity, factors affecting productivity, and related concepts such as economy and effectiveness. Two models will be presented in detail in this section: the production function and the elements of an organization.

Productivity is the ratio of a measure of output to a measure of the input required to produce the output. It can be expressed as follows:

$$\frac{\text{Output Measure}}{\text{Input Measure}} = \text{Productivity Measure}$$

There are different types of productivity depending upon the input. The most common productivity discussed in the literature is labor productivity. This is the ratio of output to a unit of labor input such as man-hours, man-years, staff-years, etc. Capital productivity, raw materials productivity, and power productivity are frequently computed in

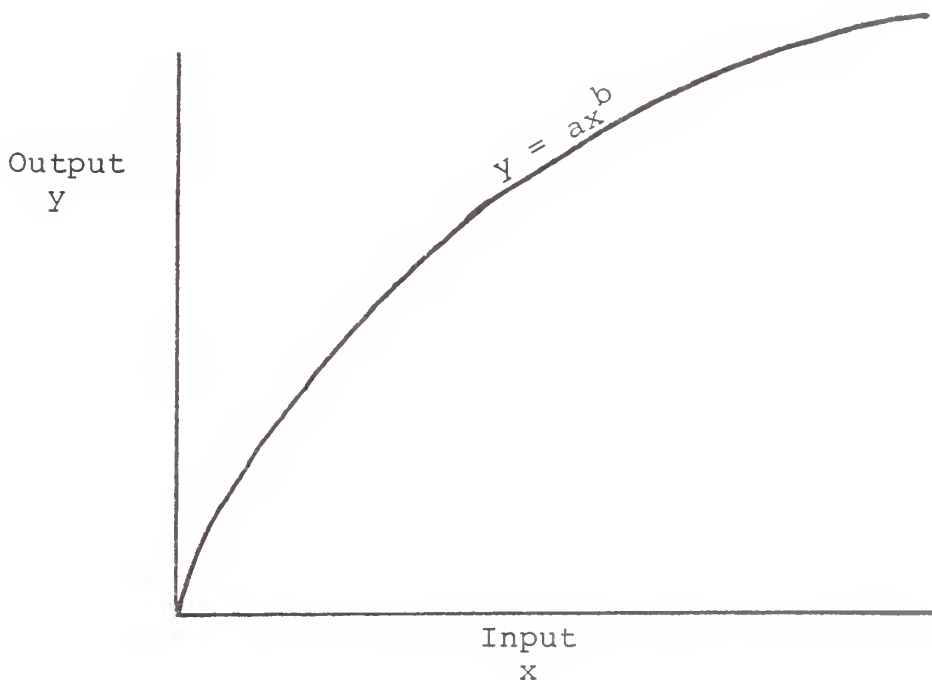
industry. Productivity is also described in terms of average productivity and marginal productivity. For U. S. Navy ships two simple average measures of productivity could be computed assuming a suitable output measure could be defined. The first is a labor productivity measure based on man-hours or men assigned. The second is a materials productivity measure based upon the amount of OPTAR expended.

To analyze the productivity of an organization, it is frequently desirable to utilize one or more methods of analysis. One method of analysis is to compute the organization's production function. The production function shows the relationship of the output of the organization and the input required to produce the output. Another method is to list or diagram the elements of an organization to determine how they interact in affecting the productivity of the organization. A third method of productivity analysis is to investigate the attitudes and perceptions of personnel in the organization concerning factors affecting productivity. A fourth method is to graph output levels and productivity levels over a period of time. Changes, fluctuations, and trends can be readily seen on a time-series plot. Then reasons for the changes can be investigated to isolate problem areas. A fifth method of productivity analysis is to compare output levels and productivity levels of one organization with similar organizations. All of these methods have been used in this study.

1. The Production Function

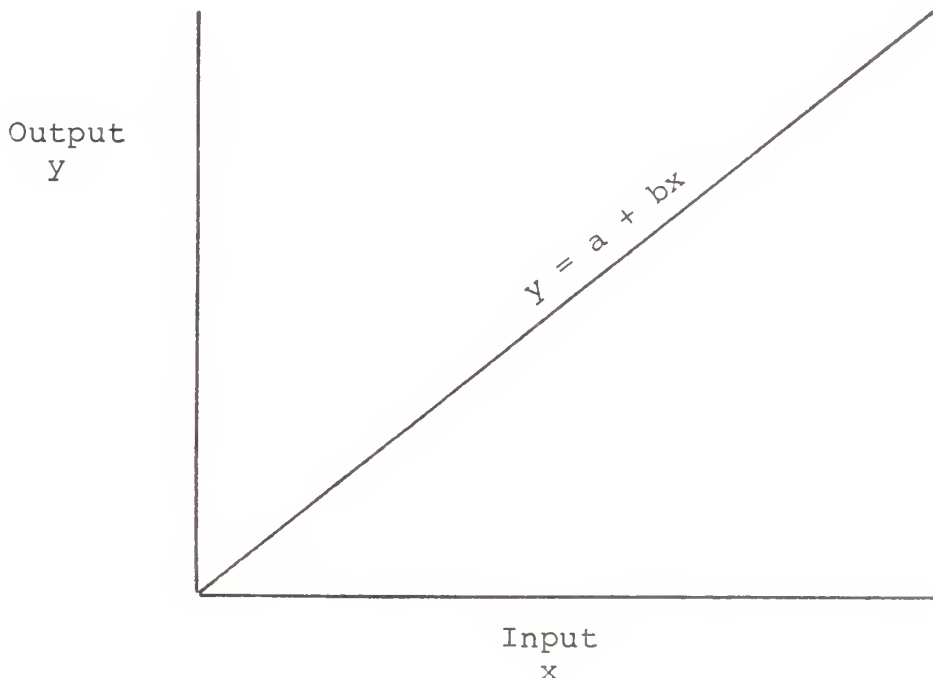
One of the most useful methods of productivity analysis is the computation of a production function. A production function is a table, graph, or equation showing the relationship between output and input. Typically, a production function has the form shown in Figure 1 when only one input variable is present. This production function is characterized by the "law of diminishing marginal returns." According to this economic law, the amount of output per unit of input decreases as the amount of input increases. This production function could be described by an equation in the form $y = ax^b$. Data points for this production function appear as a straight line when plotted on logarithmic (log-log) graph paper. The equation for a production function in this form can easily be computed using a hand-held programmable or preprogrammed calculator.

Figure 1. Typical Production Function



The simplest production function is a straight line as shown in Figure 2. The form of the equation for this production function is $y = a + bx$. Data points appear as a straight line when plotted on regular graph paper. An easy way to determine the equation describing the production function is as follows: First, list the output and input values in a table. Second, plot the output and input values on regular graph paper. If there is a general form of a straight line, then the equation describing the production function can be computed using a linear regression routine on a programmable or preprogrammed hand-held calculator. The equation can also be computed using a linear regression computer program such as SPSS (Statistical Package for the Social Sciences) or BIMED (Biomedical Computer Programs).

Figure 2. Simple Production Function



After the production function has been plotted and the equation computed, the following productivity ratios, output values, and other coefficients can be estimated:

- (1) An average productivity ratio which is equal to the y value (output) divided by the corresponding x value (input).
- (2) A marginal productivity ratio which is equal to the change in y (output) resulting from a change of one unit of x (input).
- (3) A predicted value of y (output) which is equal to the value of y (output) given a specific value of x (input).
- (4) An elasticity coefficient which is equal to the percentage change in y (output) divided by the percentage change in x (input) (Pindyck and Rubinfeld, 1976).
- (5) The coefficient of determination (r^2) which indicates the per cent of variation in y (output) which is explained by the variation in x (input) (Pindyck and Rubinfeld, 1976).

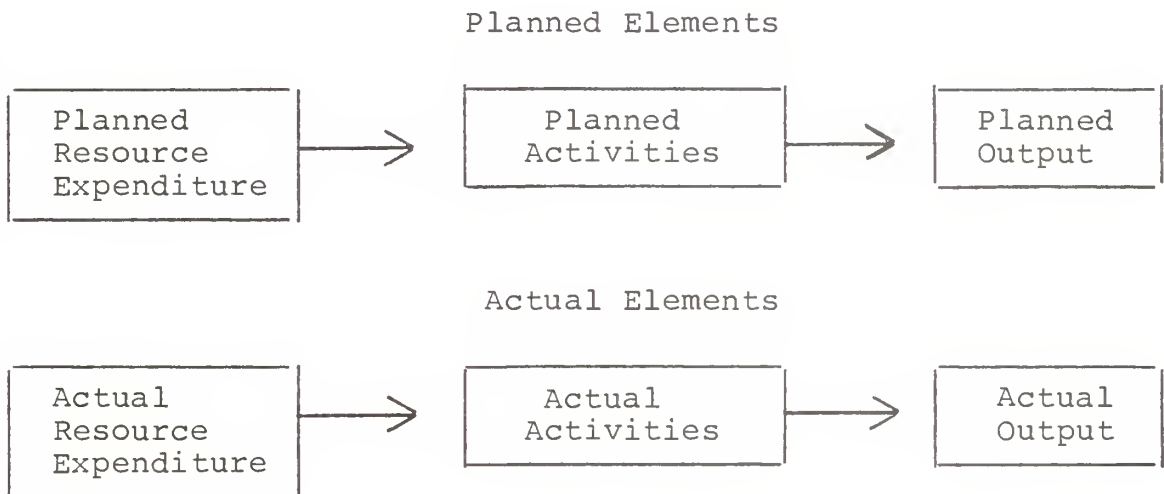
In the Department of Defense the terms efficiency, economy, and effectiveness frequently take on special connotations. These connotations are discussed in terms of the production function shown in Figure 2. Efficiency frequently connotes an increased level of output with a fixed level of input. Economy frequently connotes a reduction in the level of input without a reduction in the level of output. Effectiveness frequently connotes a measurement on the output scale and is frequently expressed as a percentage.

2. Elements of an Organization

Another method to analyze the productivity of an organization is to examine the elements of the organization.

An organization could be described in terms of three variables (Lyden and Miller, 1972): objectives, activities, resources. Figure 3 depicts an organization in terms of planned and actual elements.

Figure 3. Elements of an Organization



A productivity ratio in this example is "Actual Output" divided by "Actual Resource Expenditure". The inverse of this productivity ratio is the average cost ratio. The average cost ratio is the "Actual Resource Expenditure" divided by the "Actual Output". A measure of effectiveness is "Actual Output" divided by "Planned Output". A measure of resource expenditure is "Actual Resource Expenditure" divided by "Planned Resource Expenditure".

Using this framework, a U. S. Navy ship could be described in terms of resources, activities, and objectives as shown in Figure 4.

Figure 4. Organization Elements on a U. S. Navy Ship

<u>Resources</u>	<u>Activities</u>	<u>Objectives</u>
Men	Training	Combat Readiness
Materials	Equipment Maintenance	
Services	Logistics/Support	

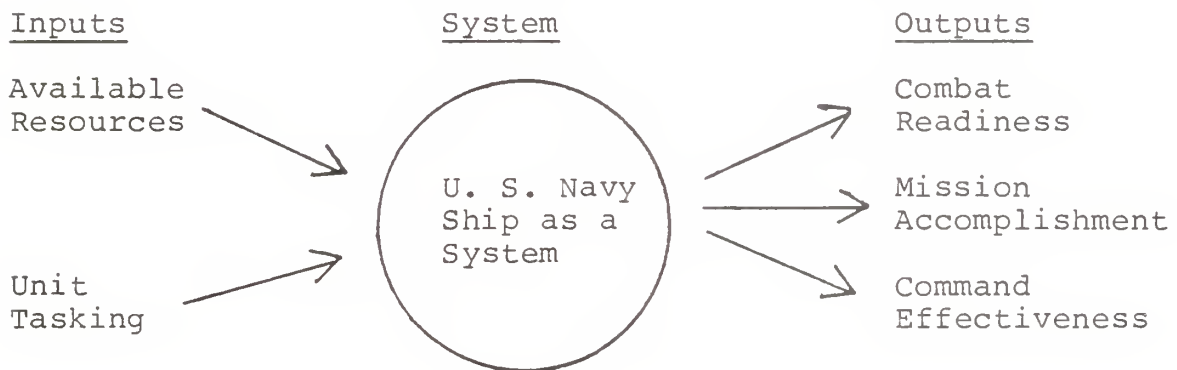
Each component of the resources, activities, and objectives listed above is measured aboard U. S. Navy ships. Records are kept on the number of men assigned, the amount of materials consumed in terms of OPTAR funds expended, the amount of services received by the ship which required OPTAR funds, the number of training activities conducted, the amount of equipment maintenance conducted, the amount of logistic or support activities such as spare parts, laundry, commissary, etc. and the level of combat readiness achieved. Data is readily available for "Planned Resource Expenditure", "Actual Resource Expenditure", "Planned Activities", and "Actual Activities".

Data is available to compute "Planned Output" and "Actual Output". However, the output data on combat readiness is subjective based on the commanding officer's assessment of how combat ready his ship is. Only the ratios

"Actual Resource Expenditure" divided by "Planned Resource Expenditure" and "Actual Activities" divided by "Planned Activities" are frequently computed aboard ships. These are computed for individual components such as men or training vice total resources or total activities. In general, no measure of a ship's productivity such as "Actual Output" divided by "Actual Resource Expenditure" is computed for U. S. Navy ships.

An organization such as a U. S. Navy ship could be described as a system which converts inputs such as resources into outputs such as services. A U. S. Navy ship could be described as shown in Figure 5.

Figure 5. U. S. Navy Ship as a System



The process by which inputs are converted to outputs could be called "thru-puts." As shown in Figure 6 "thru-puts" consist of what is to be done (content) and what methods are to be used (process).⁷

⁷ Figures 6 and 7 were provided by Norman Kjono, U. S. Navy Human Resources Management Center, San Diego, California from an unpublished paper.

Figure 6. System Elements of a U. S. Navy Ship

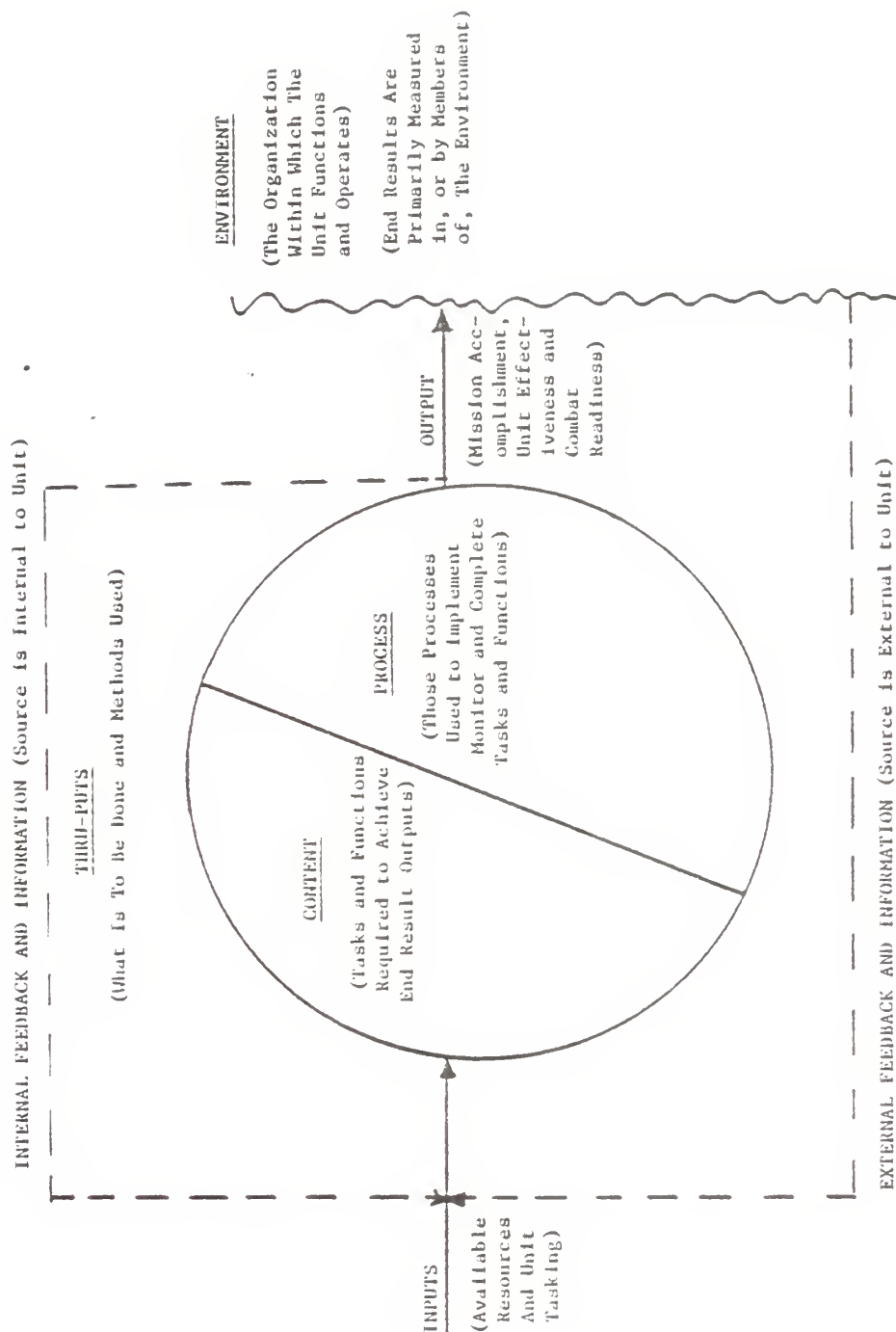
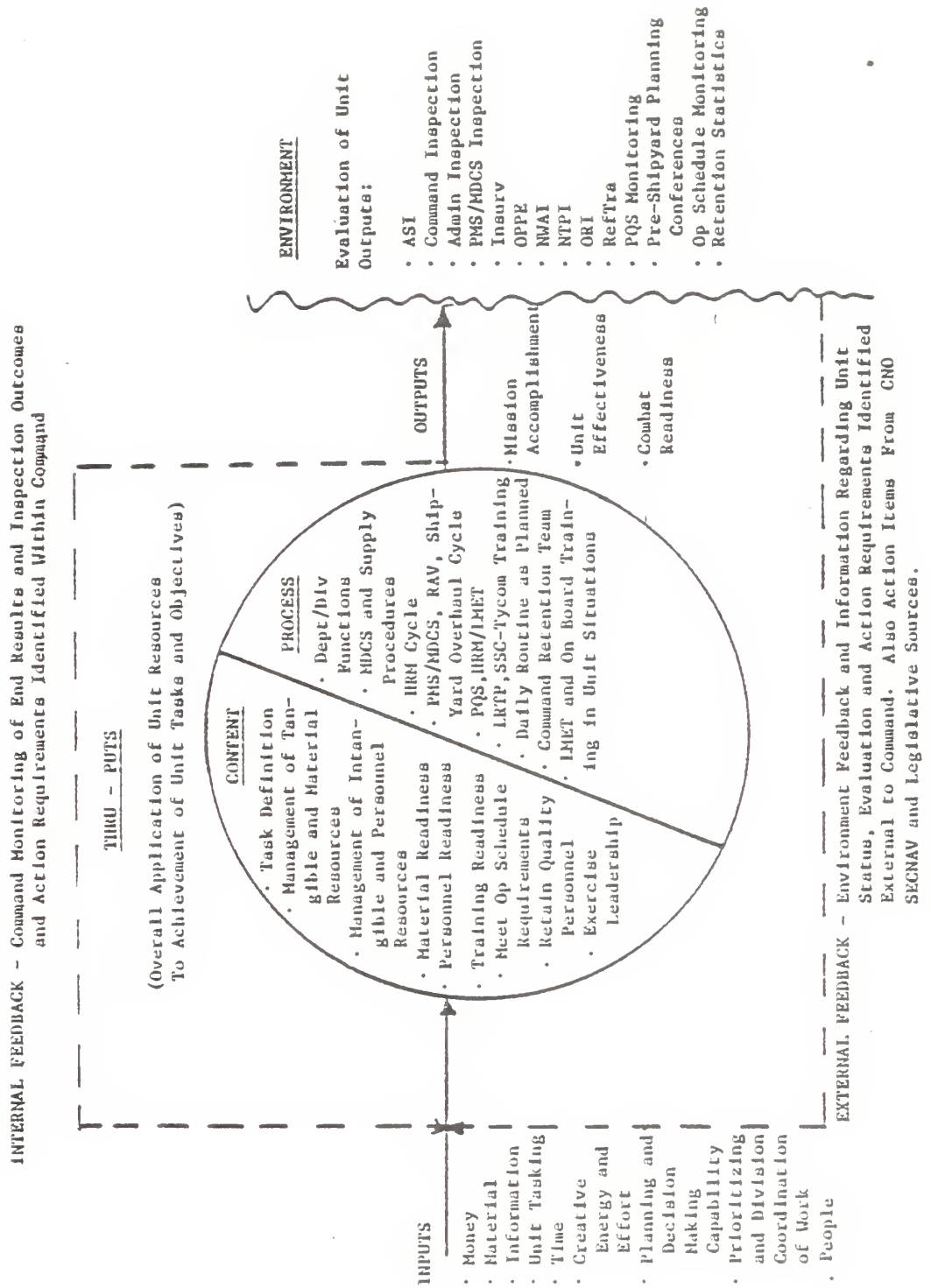


Figure 7 displays individual system elements for a U. S. Navy ship. This figure suggests that many productivity measures (output versus input measures) are possible for U.S. Navy ships. The major problem is to quantify the output measure in a manner that is meaningful and acceptable to the ship's commanding officer and higher authority.

Figures 6 and 7 address the question "what is the impact of internal and external feedback of information?" Specifically, an important question in productivity analysis is "what is the effect of the feedback of productivity information on managers and subordinates?" The effect of the feedback of productivity information can be explained in terms of "cognitive dissonance". The theory of cognitive dissonance was first postulated by Dr. Leon Festinger. Cognitive dissonance is an unpleasant reaction or tension which results when internal conflicts or inconsistencies appear (Festinger, 1957). The existence of the dissonance will motivate a person to try to reduce the dissonance to achieve consonance and to avoid situations and information which would likely increase the dissonance.

For example, productivity information when provided to a commanding officer or department head could cause dissonance if the information suggests his work centers are not as productive as he thinks they are. This would be true if the productivity information is not in agreement with his attitudes and beliefs. The dissonance causes the commanding officer or department head to either reject the information

Figure 7. Individual Elements of a U. S. Navy Ship



as being false and inaccurate or to investigate problems suggested by the productivity information.

Figure 8 shows the possible effect of the feedback of productivity information. Cognitive dissonance occurs whenever the information is not in agreement with previously held attitudes and beliefs. In the author's opinion the feedback of productivity information can have the following effects:

- cause cognitive dissonance leading to the rejection of the information or to the constructive investigation of possible problem areas,
- motivate managers to eliminate problems suggested by the productivity information,
- motivate workers (maintenance personnel on ships) to improve their performance so future productivity reports will show improved performance.

Figure 8. Effects of Feedback of Productivity Information

<u>Type of Information</u>	<u>Perception of Receiver</u>	<u>Action of Receiver</u>	<u>Potential Productivity Change in the Organization</u>
Favorable report	Good data; tells me where I am	Positive behavior	Possible improvement
Favorable report	*Bad data; not a valid measurement	No action	No effect
Unfavorable report	*Good data; identifies possible problem area	Positive behavior	Possible improvement
Unfavorable report	*Bad data; data is no good	Data denial or cover-up	No improvement and possible adverse effect

* Cognitive dissonance may occur.

Figure 8 shows possible alternative perceptions of productivity information. Cognitive dissonance, an unpleasant reaction or tension resulting when an internal conflict or inconsistency appears, can be present when either a favorable or unfavorable productivity report is received.

B. FACTORS AFFECTING PRODUCTIVITY

There are many factors which affect the level of productivity in organizations. In the most general sense the factors could be classified into two categories: physical factors and human factors. In this section factors will be examined from two points of view. First, factors affecting productivity in organizations in general will be examined. Second, factors affecting productivity on U. S. Navy ships will be examined.

1. Factors Affecting Productivity in Organizations

In terms of factors affecting productivity in organizations in general, the International Labor Office's Measuring Labor Productivity contains a comprehensive list of factors affecting labor productivity (International Labour Office, 1969). As shown in Table I the factors are classified as being general factors, organizational and technical factors, and human factors. The value in examining factors affecting productivity is that changes can be made in the factors to improve productivity.

The Annual Report to the President and the Congress on Productivity Programs in the Federal Government FY 1974 cited many factors which affect productivity in organizations.

Table I. Factors Affecting Labor Productivity⁸

General Factors

Climate
Geographical distribution of raw materials
Fiscal and credit policies
General organization of the labor market
Proportion of the labor force to the total population,
degree of unemployment, of labor shortage, and of
labor turnover
Technical centers and information concerning new
techniques
Commercial organization and size of market
General scientific and technical research
Variations in the composition of the output
Influence of low-efficiency plants and their varying
proportion in total output

Organization and Technical Factors

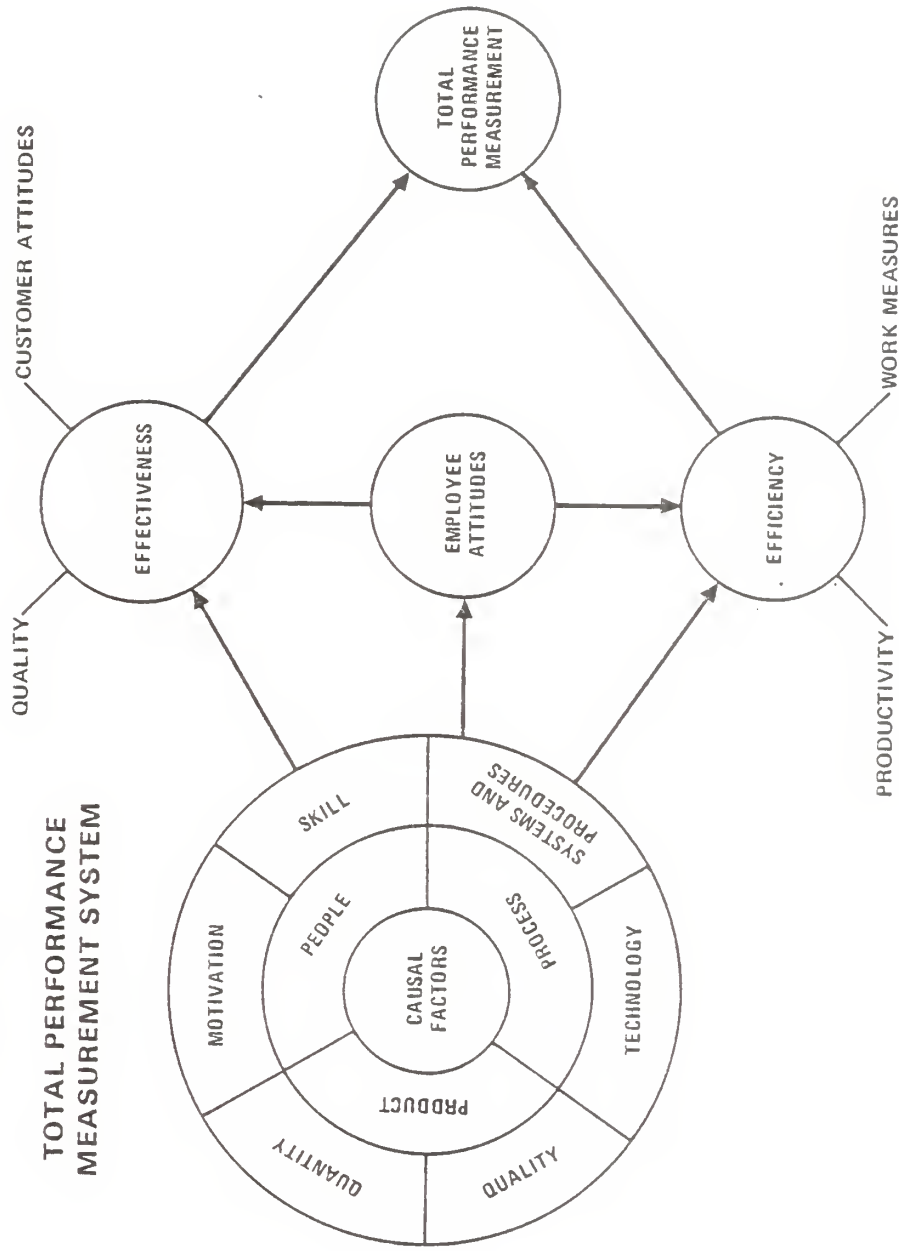
Degree of integration
Percentage of capacity used
Size and stability of production
Quality of raw materials
Adequate and even flow of materials
Subdivision of operations
Balancing of equipment
Multiple machine systems
Control devices
Quality of output
Rationalization and standardization of work and material
Layout and location of the plant
Maintenance and engineering services: safety, sound,
ventilation, air conditioning, telephone, etc.
Availability, fitness and accessibility of tools
Wear and tear of machines and tools
Amount of machinery (or power) available per worker
Proportion of maintenance labor to operating labor
Length and distribution of working hours
Selection of personnel

Human Factors

Labor-management relations
Social and psychological conditions of work
Wage incentives
Adaptability to, and like for, the job
Physical fatigue
Composition (age, sex, skill, and training) of the labor
force
Organization of the spirit of emulation in production
Trade union practices

⁸International Labour Office, Measuring Labour Productivity, p. 13, Presses Centrales, Lausanne, SA, 1969.

Figure 9.



Many factors are shown in Figures 9 and 10.⁹ The importance of human factors as indicated by employee attitudes is shown in Figures 9 and 10. Concerning attitude measurement, the annual report stated:

"Attitude measurement, properly administered, and used, gives an added dimension to performance assessment and problem diagnosis that is powerful in identifying significant targets of opportunity for performance improvement. The major objective of employee attitude measurement is to provide top management with the information needed to improve the human side of productivity and effectiveness."

2. Factors Affecting Productivity on U. S. Navy Ships

Table II is a list of factors which affect the level of productivity on U. S. Navy ships.

Table II. Factors Affecting Productivity
on U. S. Navy Ships

<u>Physical Factors</u>	<u>Human Factors</u>
Tools	Supervision
Test equipment	Performance evaluations
Lighting	Praise
Supplies	Rewards
Technology	Reprimands
State of equipment	Penalties
maintenance	Motivation
Age of equipment	Job skills
Temperature	Experience
Sound	Training
Ventilation	Working hours
Work measurement	Job satisfaction
Space to work	Number of personnel
	Disruptions
	Goals and objectives
	Fatigue
	Attitudes
	Theft and pilferage
	Information

⁹ Figures 9 and 10 are published in the JFMIP Annual Report to the President and Congress on Productivity Programs in the U. S. Federal Government FY 1974. Permission was received from JFMIP to reproduce these figures and other portions of the annual report.

Figure 10.

A TOTAL SYSTEMS APPROACH

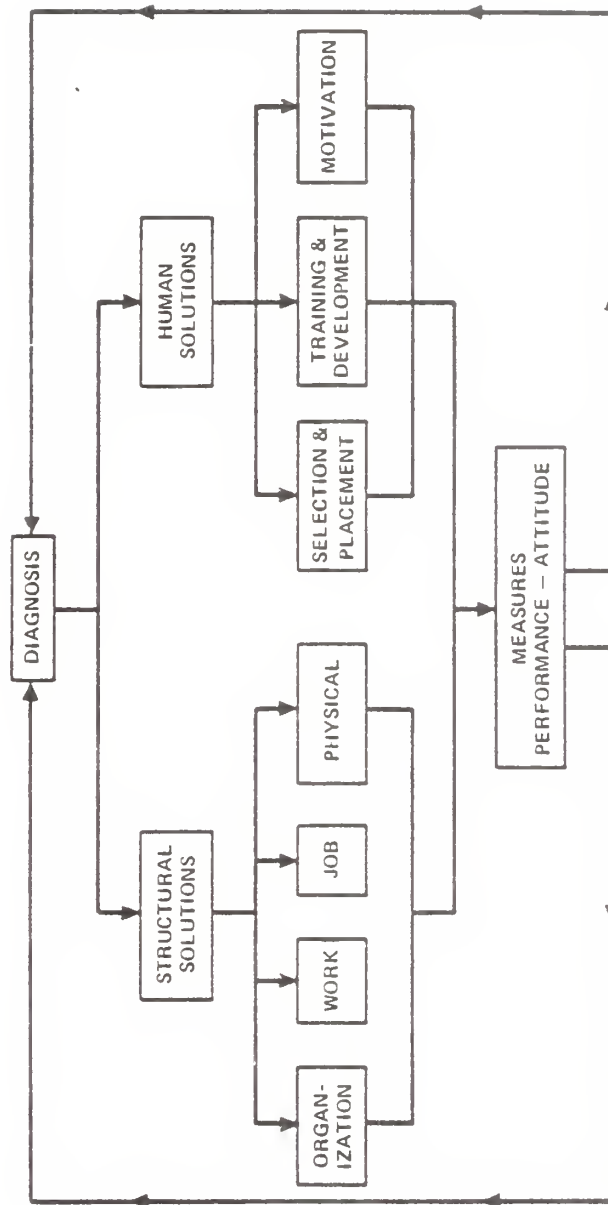


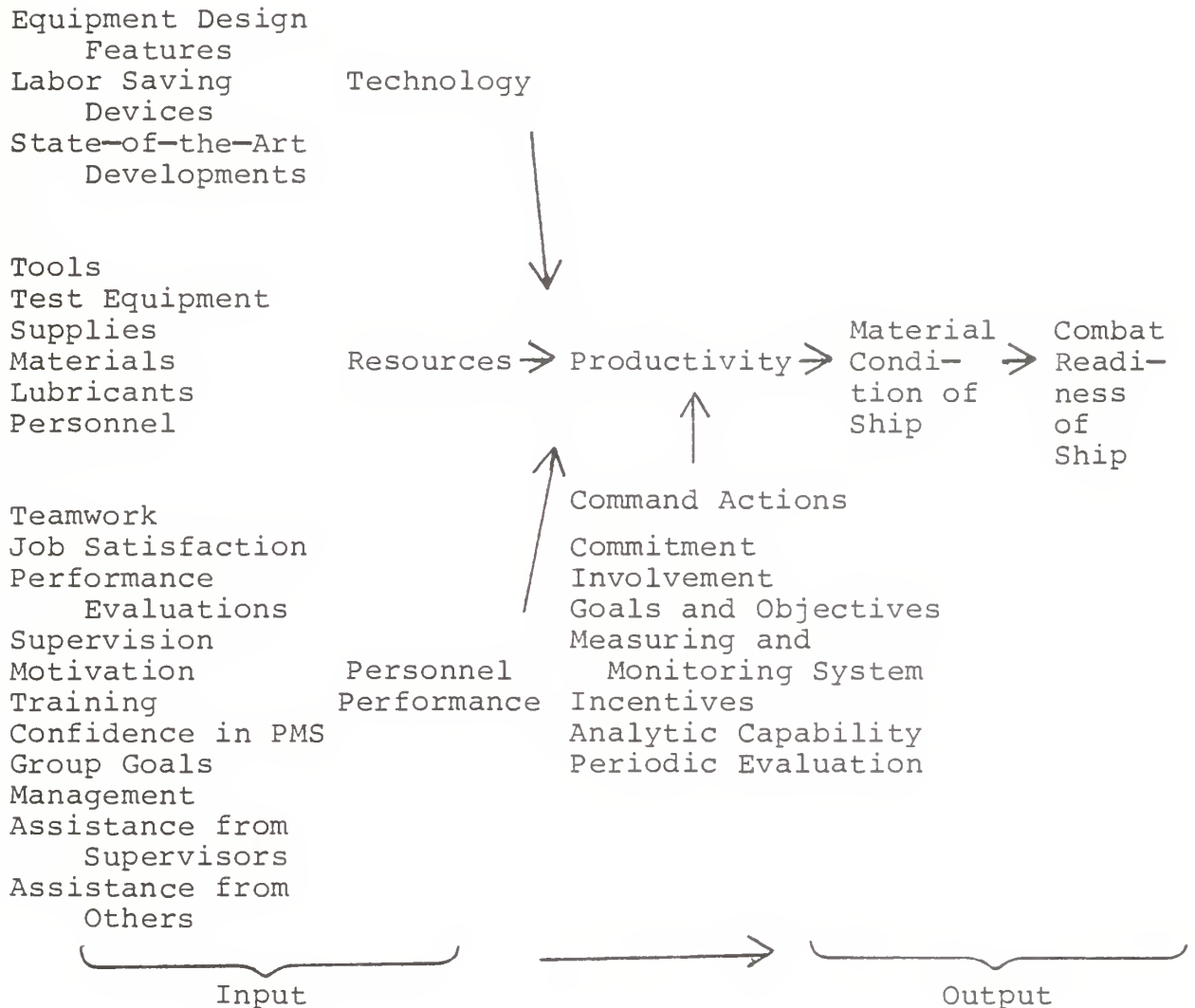
Figure 11 shows the author's opinion of how the general factors of technology, resources, and personnel performance affect productivity on a U. S. Navy ship, the material condition of the ship, and eventually the combat readiness of the ship. Figure 11 also lists command or management actions which could favorably impact on the productivity of the ship.

The enhancement of productivity is accomplished principally by implementing management changes and policies which favorably affect the input factors shown in Figure 11 or which eliminate weaknesses and impediments to higher productivity in the organization. For example, a commanding officer or department head could implement policies to improve the level of technology, the availability of resources used in work such as tools and supplies, and the creation of favorable work attitudes among the personnel.

Additionally, in the author's opinion there are seven major factors which positively affect productivity on U. S. Navy ships. These are:

- (1) The statements and objectives concerning productivity and efficiency by high-ranking officers and civilian personnel throughout the Navy.
- (2) The requirements stated in U. S. Navy Regulations, 1973 and other publications and instructions.
- (3) The high level of experience, competence, and motivation of Navy personnel.
- (4) Limits set by superiors regarding personnel manning, steaming hours, equipage allowances, OPTAR spending levels, etc.

Figure 11. Factors Affecting Shipboard Productivity



Note: An effective way to provide an increased level of output without an increased level of input is through increased productivity. The focus of the effort should be toward the development of specific command actions involving any of the input factors which result in an improved level of productivity.

(5) The 3M/PMS System.

(6) The Human Resources Management Program.

(7) The knowledge of navy managers that a higher degree of attainment of objectives can be achieved through greater productivity and efficiency.

In the author's opinion there are 12 major factors which adversely affect productivity on U. S. Navy ships.

These are:

(1) Inability to measure productivity.

(2) An evaluation system for personnel performance for officer and enlisted personnel which does not emphasize the importance of productivity.

(3) Personnel who lack job satisfaction who are consequently dissatisfied, disinterested, and unmotivated.

(4) Inexperienced and untrained personnel.

(5) Frequent crisis environment to effect equipment maintenance due to equipment breakdowns, impending operations, etc.

(6) Inadequate tools, test equipment, and supplies.

(7) Training which does not promote the learning of skills to improve productivity and efficiency.

(8) Lack of awareness of total costs, i.e., personnel, fuel, utilities, repair services, etc.

(9) Theft and pilferage of tools and materials.

(10) Attitudes such as "we must spend everything we have or we won't get this much next quarter" and "the more we get, the better we'll be."

(11) Negative attitudes about PMS, the command, and the Navy.

(12) Lack of incentives to motivate personnel to improve productivity.

In the author's opinion the lack of a clearly defined measure of productivity is a principal impediment to achieving higher levels of productivity. While the general goal of productivity and efficiency is expressed by practically every commander and commanding officer in the U. S. Navy, no specific, quantitative goals can be expressed without a clearly defined measure of productivity or efficiency.

Again, in the author's opinion the lack of emphasis on evaluating productivity or efficiency on officer and enlisted personnel evaluation forms is a principal impediment to achieving higher levels of productivity. The present evaluation system does not adequately measure, reward, or provide incentives for improved productivity.

C. BENEFITS AND COSTS OF A PRODUCTIVITY MEASUREMENT AND ENHANCEMENT PROGRAM

Many persons in the Department of Defense and the Department of the Navy pose the questions:

- Why worry about productivity measurement?
- What is the benefit of measuring productivity?
- Is productivity measurement worth the cost of collecting all the required data?
- Is productivity measurement applicable to U. S. Navy ships?

These are reasonable questions. The answers are not simple. In most cases only the on-scene manager can answer them.

However, in general, organizations can improve their performance and mission accomplishment with a productivity measurement and enhancement program. The program must be tailored to the specific mission and needs of the organization. The program can be simple or complex. With such a program an organization can improve its productivity and can accomplish its objectives and missions with less resources than were previously required. This is becoming increasingly important in a world of shrinking resources. Getting more done with less resources is the essence of effective management.

The literature is full of reports by profit, non-profit and government organizations which have successfully employed productivity measurement and enhancement programs. These programs have improved their levels of profit, services, and accomplishment. The Department of Commerce Situation Report Productivity Series Bulletin No. 3 (Appendix D) reports:

"Productivity measurement serves as a tool for productivity enhancement in four ways. First, the installation of a measurement system and the discussion preceding it heighten staff awareness of the importance of raising output per unit of input for the maintenance of profitability. Second, observed changes in the numbers often have diagnostic value, pointing to bottlenecks and other impediments to superior company performance. Third, the changes in the numbers also allow assessment of the consequences of intended remedial actions. Fourth, continuing discussion of the validity of the measurements promotes productivity-consciousness, contributing to an atmosphere congenial to operational as well as statistical improvement.

"Even crude initial productivity estimates can prove beneficial to a company's performance. Their availability and use provide occasion for serious communication between management and employees on matters of mutual concern. In the course of such interaction, illuminating insights are often generated and transmitted."

However, it should be noted that productivity measurement and information are strictly an aid to good management. They can have beneficial effects. If abused, such as using productivity information solely without other information, productivity information can have adverse effects on an organization.

A productivity measurement and enhancement program on U. S. Navy ships using maintenance, personnel and OPTAR cost information can have favorable and unfavorable effects depending upon the way it is implemented and operated. Some of the favorable effects are:

- (1) The program can result in greater accomplishment of PMS and therefore improve the material condition of the ship.
 - (2) The program can result in a decrease in the consumption of resources. Jobs could be done with fewer personnel and less expenditure of OPTAR funds.
 - (3) The program can result in increased motivation of work center personnel to be efficient and to be less wasteful of time, material, and supplies. It can increase their motivation because of stated goals, a set measurement procedure, incentives, and feedback of information.
 - (4) The program can result in greater awareness of efficiency, cost-consciousness, and time-consciousness by work center personnel.
 - (5) The program can extend and improve the PMS system.
 - (6) The program can result in improved management decisions.
- The program can provide excellent and useful management

information. This information in the form of productivity indices can be used along with quantitative, qualitative, and subjective information to make management decisions on allocation of resources, scheduling of work, submitting requests for additional resources, and evaluating work center performance. The productivity indices, when used with other information, can be used to detect problem areas and unfavorable trends. The indices can be used as a basis for granting awards and rewards for superior performance. The indices can be used to support requests for additional resources when it can be shown that it would be impossible to achieve a given output with present resources.

Additionally, the program, if not properly implemented and administered, could produce unfavorable effects. Some of these are:

- (1) The program could result in generating excessive paperwork.
- (2) The program could result in poorer quality of work if work center personnel perceived that quantity not quality of work was desired. To avoid poorer quality of work, work center supervisors and above should continue to closely supervise the accomplishment of PMS. They should rigorously ensure that each maintenance action is properly accomplished with the proper tools, with the proper materials, by doing every step on the MRC (Maintenance Requirement Card), and by accomplishing the maintenance action on each piece of equipment on the EGL (Equipment Guide List) as applicable.
- (3) The program could result in a misuse of the productivity data. The productivity indices alone are not useful without

other information such as subjective opinions. A statement such as "Work Center A is better than Work Center B because Work Center A has a higher productivity index than Work Center B" is a highly inaccurate, misleading, and false statement. The statement is a misuse of productivity data because it doesn't include information on possible reasons for differences such as differences in personnel, mission requirements, availability of resources, and other factors. Productivity indices must be used with other data and information to make valid statements, judgments, and decisions.

(4) The program could generate adverse or negative attitudes and emotions among work center personnel. Some individuals may feel that measurement of productivity "can't be done on a ship" and is therefore "unfair". Some individuals may feel frustrated if they feel that productivity goals are set unrealistically high. Additionally, a department head who says "working hours will be extended one hour per day until the productivity indices improve" will generate a great amount of ill feelings toward the program. To avoid generating adverse or negative attitudes and emotions work center supervisors and above should stress the positive benefits of the program and use the productivity indices in a positive manner.

(5) The program could provide information which is inaccurate. Relating the amount of PMS accomplished in a work center with the number of men assigned and with the amount of OPTAR spent may not be a useful measure in some departments and work centers. This is true if a large portion of the personnel

and OPTAR are used for activities not related to PMS accomplishment. To avoid this, an output measure should be selected which is representative of the activities of the work center. Another solution to this problem would be to submit feedback forms to include more work center activities in the PMS system. This would have the beneficial effect of extending the system.

D. FORMULATION OF PRODUCTIVITY MEASURES FOR U. S. NAVY SHIPS

The process of formulating productivity measures is a simple process of dividing an output measure by an input measure. What is difficult is defining and measuring the output and input measures. In attempting to formulate productivity measures for U. S. Navy ships the following four steps are followed:

- (1) Define the purpose and uses for the productivity measures.
- (2) Define output measures.
- (3) Define input measures.
- (4) Define productivity measures utilizing the most suitable output and input measures.

Four major purposes and uses of productivity measures for U. S. ships are envisioned. These are:

- (1) To provide an aid for shipboard management to provide information which may be useful in planning, resource allocation, and control.
- (2) To provide an incentive for shipboard personnel to achieve higher levels of productivity.
- (3) To provide a means to promulgate productivity goals.

(4) To provide a means to present information to officers and enlisted personnel to compare planned performance with actual performance.

The problem of defining a suitable output measure is by far the most difficult aspect of formulating a productivity measure for U. S. Navy ships. A ship has no readily measurable output such as a factory or store would have. The output of a ship is its ability to fight and to accomplish its assigned missions in a hostile environment. Its output is its combat readiness. There is presently no accepted method to physically measure the combat readiness of a ship. The best one can do is to utilize a subjective evaluation of the combat readiness of a ship or to use some measure of a ship's activities such as equipment maintenance or training. The following are a number of possible output measures for U. S. Navy ships:

- (1) Number of underway days.
- (2) Number of pieces of equipment fully operational.
- (3) Number of maintenance actions completed.
- (4) Maintenance actions completed multiplied by a weight (importance) factor.
- (5) Number of PQS (Personnel Qualification Standards) points achieved.
- (6) Commanding officer's subjective estimate of the overall combat readiness of the ship.

Each of these output measures is unsatisfactory in one or more ways. There is no perfect output measure. There is no

output measure which everyone will accept. The best one can do is to select an output measure with the most positive features and the least negative features.

Next, the input measures are defined. The following input measures could be used for U. S. Navy ships:

- (1) Number of personnel assigned.
- (2) Number of man-hours used.
- (3) Amount of OPTAR consumed.
- (4) Amount of OPTAR obligated.
- (5) Total resources used (OPTAR funds, repair funds, personnel funds, etc.)

Finally, possible productivity measures are formulated by selecting the most suitable output and input measures. In the author's opinion the following are the two simplest and most suitable productivity measures for U. S. Navy ships:

- (1) Personnel Productivity Index = number of planned maintenance actions accomplished/number of personnel assigned.
- (2) OPTAR Productivity Index = number of planned maintenance actions accomplished/amount of OPTAR consumed.

For example, a ship which completed 1000 planned maintenance actions in a quarter with 250 men assigned and spent (consumed) \$10,000 in OPTAR would have the following indices:

- (1) Personnel Productivity Index = $1000/250 = 4.0$ planned maintenance actions per man.
- (2) OPTAR Productivity Index = $1000/\$10,000 = .10$ planned maintenance actions per OPTAR dollar consumed.

The numerator of the productivity indices is the output measure of planned maintenance actions accomplished. This output measure was selected by the author for the following reasons:

(1) It is easily computable on U.S. Navy ships by counting X's and circles on PMS schedules which indicate the completion or non-completion of scheduled or non-scheduled maintenance actions.

(2) It is a measure used in the 3M/PMS System to compute the PMS Recorded Accomplishment Rate in accordance with OPNAVINST 4790.8 of 20 June 1975, entitled "Measuring PMS Performance Rate". The output measure is the numerator in the formula for computation of the PMS Recorded Accomplishment Rate. The formula is:

$$\text{PMS Recorded Accomplishment Rate} = \frac{\begin{array}{l} \# \text{ of MR's recorded} \\ \text{as fully} \\ \text{accomplished} \end{array} + \frac{1}{2} \left[\begin{array}{l} \# \text{ of MR's recorded} \\ \text{as partially} \\ \text{accomplished} \end{array} \right]}{\# \text{ of MR's scheduled.}}$$

An MR (Maintenance Requirement) is a maintenance action listed on an MRC (Maintenance Requirement Card). An example of an MR is the lubrication of a pump or the adjustment of a fan belt. If a ship recorded 60 MR's fully accomplished and 40 MR's partially accomplished, and scheduled 100 MR's, the ship would have a PMS Recorded Accomplishment Rate of .80. This was computed as follows: $(60 + \frac{1}{2}(40))/100 = .80$.

(3) It is understandable by shipboard personnel since the 3M/PMS System is the maintenance system used aboard U. S. Navy ships.

(4) It is not limited by definition as many of the other output measures are such as underway days per month.

(5) It assumes that planned maintenance actions are accomplished whenever corrective maintenance is required. It is the Fleet Commander's and Type Commander's policy in both the Atlantic and Pacific Fleets that planned maintenance actions be accomplished whenever corrective maintenance is required. For example, when a pump breaks down, the proper procedure is to check the applicable MCR's (Maintenance Requirement Cards) and accomplish all the MR's (Maintenance Requirements) that are required and related to correcting the casualty.

The output measure of planned maintenance actions accomplished has the following limitations:

(1) Different MR's (Maintenance Requirements) have substantially different time and material requirements. For example, one MR can be completed in five minutes while another MR could only be completed in five hours.

(2) Different ships have different policies regarding the scheduling and recording of MR's. For example, one ship may have one line on a PMS schedule for all the small diesel engines on the ship while another ship may have a separate line for each small diesel engine on the ship. A completed MR on the first ship would be for all the small diesels; a completed MR on the second ship would be for only one small diesel.

(3) The problem of inaccurate or false reporting of the number of planned maintenance actions accomplished is present.

Inaccurate or false reporting could include exaggerating the number of planned maintenance actions accomplished or reporting planned maintenance actions accomplished on equipment that, in fact, was not accomplished. In the U. S. Navy false reporting of planned maintenance actions accomplished is frequently referred to as "gundecking". Adequate supervision, emphasis on accurate reporting, and cautious use of productivity information for personnel evaluation purposes can minimize the problem of inaccurate or false reporting.

(4) The output measure of planned maintenance actions accomplished does not take into account the quality of work performed.

The output measure of planned maintenance actions accomplished is considered to be a usable output measure for U. S. Navy ships even with its limitations. A substantial improvement in this output measure would be to weight each MR in some manner as to its importance, its time requirements, its materials requirements, or by some other factor.

IV. THE STUDY

A. OVERVIEW OF THE STUDY

In conjunction with this research project, a study was designed to actually measure productivity on 26 U. S. Navy ships. These 26 ships were participating in the U. S. Pacific Fleet Equipment Maintenance and Related Maintenance (EMRM) Project.¹⁰ The majority of the data required for the study was already being collected for the EMRM Project.

The objectives of the study were as follows:

- determine if productivity could be measured on U. S. Navy ships,
- compute productivity ratios for 26 U. S. Navy ships,
- identify differences between high and low productivity ships.

There were two purposes in identifying differences between high and low productivity ships. The first purpose was to determine if high productivity ships were superior ships. If high productivity ships, in general, were superior ships in other areas as shown by inspection results, awards won, etc., this would indicate that the productivity measurement was reasonably accurate and valid. However, if the high productivity ships were not superior in other areas, this would

¹⁰The 26 ships were the control group for the U. S. Pacific Fleet Equipment Maintenance and Related Maintenance (EMRM) Project. The U. S. Pacific Fleet EMRM Project was coordinated by the Commanding Officer, Navy Manpower and Material Analysis Center, Pacific.

suggest that the productivity measurement was not accurate, not valid, or not meaningful. The second purpose in identifying differences between high and low productivity ships was to identify factors which were related to the level of productivity on the ships. These factors were identified by administering an attitude survey questionnaire, the Ship Efficiency Questionnaire, developed at the Naval Postgraduate School. The questionnaire is shown in Appendix A. Each of the 16 questions on the questionnaire measures an attitude or a perception regarding a factor which might be related level of productivity on the ships, such as adequacy of tools, extent of praise, etc. The questions are grouped together to form five indices:

- adequacy of management,
- adequacy of resources,
- extent of teamwork,
- extent of positive leadership, and
- extent of negative leadership.

There were 2212 responses to the questionnaire. The adequacy of tools, adequacy of supplies, the extent of teamwork, and adequacy of planning were found to be important factors related to the level of productivity on the ships. It was found that nearly 40 per cent of the respondents felt that they did not have adequate tools and supplies to work efficiently. This suggests a possible problem on many ships.

For this study data was collected over a nine month period from 1 November 1975 to 31 July 1976. There were three

principal categories of data collected. First maintenance, personnel, and OPTAR cost data (repair part costs) were collected. The purpose of collecting this data was to compute productivity ratios for each of the 26 U. S. Navy ships. This data was collected using a weekly maintenance report from the EMRM Project shown in Appendix J. This data was collected for the six month period 1 November 1975 to 30 April 1976. Second, performance data on inspections and awards won was collected. The principal purpose in collecting this data was to determine if ships with high productivity ratios were superior ships as measured by other means. This data was collected for Fiscal Year 1976 which included the period of time maintenance data was collected. Third, enlisted personnel attitude data was collected utilizing the Ship Efficiency Questionnaire. The purpose of collecting this data was to identify factors related to the level of productivity on the ships.

As shown in Table III over 5000 documents, reports, and questionnaires were reviewed and used as sources of data in this study. These documents, reports, and questionnaires contained over 300,000 individual data elements which were used in this study. In compiling, displaying, and analyzing this data over 100 computer programs were written and run with this data.

TABLE III. Documents, Reports, and Questionnaires
Reviewed and Utilized

<u>Type</u>	<u>Approximate Number</u>
Maintenance	2000
Personnel	150
Inspection Results	50
Awards	200
NAVFORSTAT Reports	600
OPTAR Reports	150
Attitude Questionnaires	<u>2212</u>
Total	5362

Data was collected on the following U. S. Navy ships:

MARS (AFS-1), SHASTA (AE-33), PONCHATOULA (AD-148), KAWISHIWI (AD-146), WICHITA (ADR-1), ABNAKI (ATF-96), TAWAKONI (ATF-114), MOLALA (ATF-106), REEVES (CG-24), STERETT (CG-31), TOWERS (DDG-9), HOEL (DDG-13), LANG (FF-1060), BADGER (FF-1071), KIRK (FF-1087), COOK (FF-1083), MOBILE (LKA-115), DENVER (LPD-9), DULUTH (LPD-6), TRIPOLI (LPH-10), PT. DEFIANCE (LSD-31), MT. VERNON (LSD-39), FRESNO (LST-1182), TUSCALOOSA (LST-1187), BARBOUR CTY (LST-1195), BRISTOL CTY (LST-1198).

These ships represent a cross section of U. S. Navy ships. The displacement of these ships ranged from approximately 1800 tons for the ATF's (Fleet Tugs) to approximately 18,000 tons for the LPH (Amphibious Assault Ship). The number of personnel assigned to these ships ranged from approximately 60 men for the ATF's to approximately 500 men for the LPH.

In addition to the findings and recommendations from the study, three "productivity items" were developed for use aboard U. S. Navy ships as desired by individual commanding

officers. The first "productivity item" is the Shipboard Productivity Improvement Program shown in Appendix A. It is written in the form of a U. S. Navy instruction. The second "productivity item" is the Ship Efficiency Questionnaire shown in Appendix A. It is considered a valid instrument to measure attitudes and perceptions of enlisted personnel aboard U. S. Navy ships regarding factors related to the level of productivity. The third "productivity item" is the Ship Productivity Report shown in Appendix C. It is the format for an automated (computer-based) report that contains productivity information.

B. PRODUCTIVITY MEASUREMENT ON 26 U. S. NAVY SHIPS

1. Input and Output Measures

The first step in measuring productivity in an organization is to measure inputs and outputs in the organization. For the 26 U. S. Navy ships in this study, the following input and output measures were used:

Output - planned maintenance actions accomplished,

Input (personnel) - average number of men assigned,

Input (materials) - amount of OPTAR consumed for repair parts.

These output and input measures were computed as follows:

- planned maintenance actions accomplished = number of MR's (Maintenance Requirements such as lubricating a pump) recorded as being fully accomplished + $1/2$ the number of MR's recorded as being partially accomplished,

- average number of men assigned = number of enlisted men assigned to the ship on the first day of the month + the number of enlisted men assigned to the ship on the last day of the month $\div 2$,

- amount of OPTAR consumed for repair parts = the cost of all the repair parts used during the month in maintenance.

Table IV is a summary of the output and input measures for 26 U. S. Navy ships. The actual names of the ships are not listed to provide confidentiality for individual ships. As can be seen in Table IV, the average output of planned maintenance actions accomplished for the 26 ships was 3026.7 actions per month, the average number of men assigned was 264.5 men per month, and an average amount of OPTAR consumed for repair parts was of \$6876.68 per month.

Frequently it is desirable to examine changes or trends in the output and input measures. Figure 12 is a time-series plot of the output measure planned maintenance actions accomplished for the six month period from 1 November 1975 to 30 April 1976. As can be seen in Figure 12, the number of planned maintenance actions accomplished per month fluctuated rather markedly. Reasons for these fluctuations were not determined in this study.

Examination of the data in Table IV and Figure 12 suggest the following:

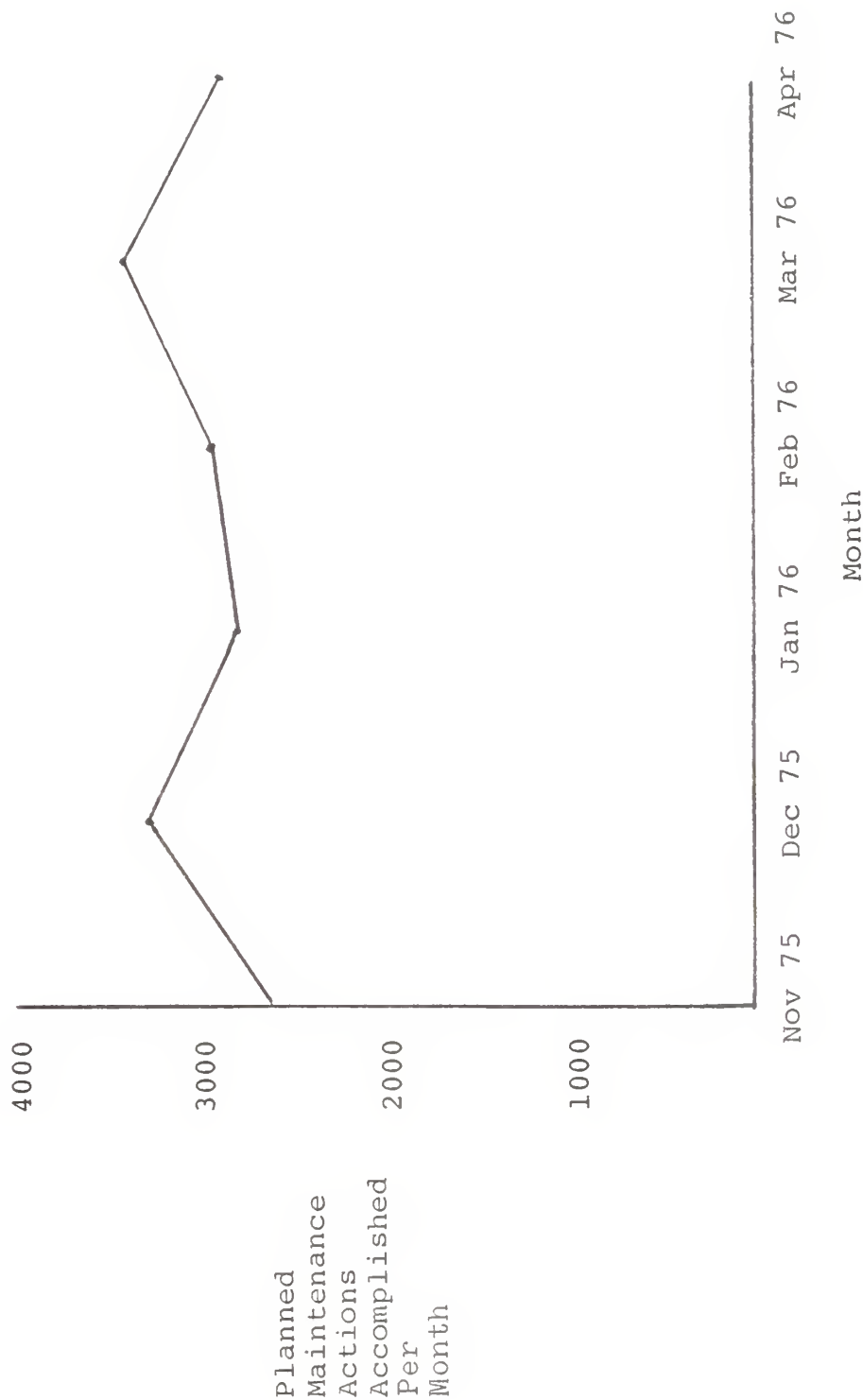
- there is substantial variability among the ships and the types of ships in terms of output and input measures,

- output and input measures can be computed for U. S. Navy ships once they are clearly defined,

Table IV. Output and Input Measures for 26 U.S. Navy Ships
(Average per Month)

<u>Ship</u>	<u>Planned Maintenance Actions Accomplished</u>	<u>Average Number of Men Assigned</u>	<u>OPTAR \$ Consumed for Repair Parts</u>
Combatant Type (mean)	3218.3	274.5	\$11723.10
01	3861.6	368.8	22220.66
02	3395.8	290.3	8284.50
03	2410.8	208.3	8133.50
04	2394.3	227.2	9823.50
05	4502.7	349.2	14410.83
06	3398.4	299.3	10510.50
07	2877.9	236.5	12471.16
08	2905.3	216.8	7930.00
Amphibious Type (mean)	3233.2	294.0	\$ 5714.63
09	2759.4	316.8	4198.83
10	4913.5	389.3	5355.83
11	4518.3	511.7	9013.33
12	2874.0	282.5	5537.33
13	2606.9	201.2	4517.66
14	4008.9	390.7	6832.50
15	3066.3	285.3	7872.66
16	2206.5	187.7	2322.83
17	2202.1	184.0	6159.83
18	3176.3	191.7	5335.50
Service Type (mean)	2576.9	217.4	\$ 3482.85
19	5609.5	353.5	5875.66
20	1954.8	276.2	3914.67
21	4206.5	345.5	5160.50
22	875.8	61.7	2567.17
23	3795.9	301.0	4917.66
24	2396.9	270.2	2996.83
25	805.1	66.2	825.83
26	970.8	64.8	1604.50
Total (mean)	3026.7	264.5	\$ 6876.68
Standard deviation	1268.0	104.8	\$ 5666.26

Figure 12. Planned Maintenance Actions Accomplished
per Month for 26 U. S. Navy Ships



- output and input measures alone without other information provide little useful information to evaluate performance or to identify problem areas,

- output and input information must be used with other information such as output and input objectives and targets for them to be useful,

- changes in the output and input measures can be best seen on a time-series plot,

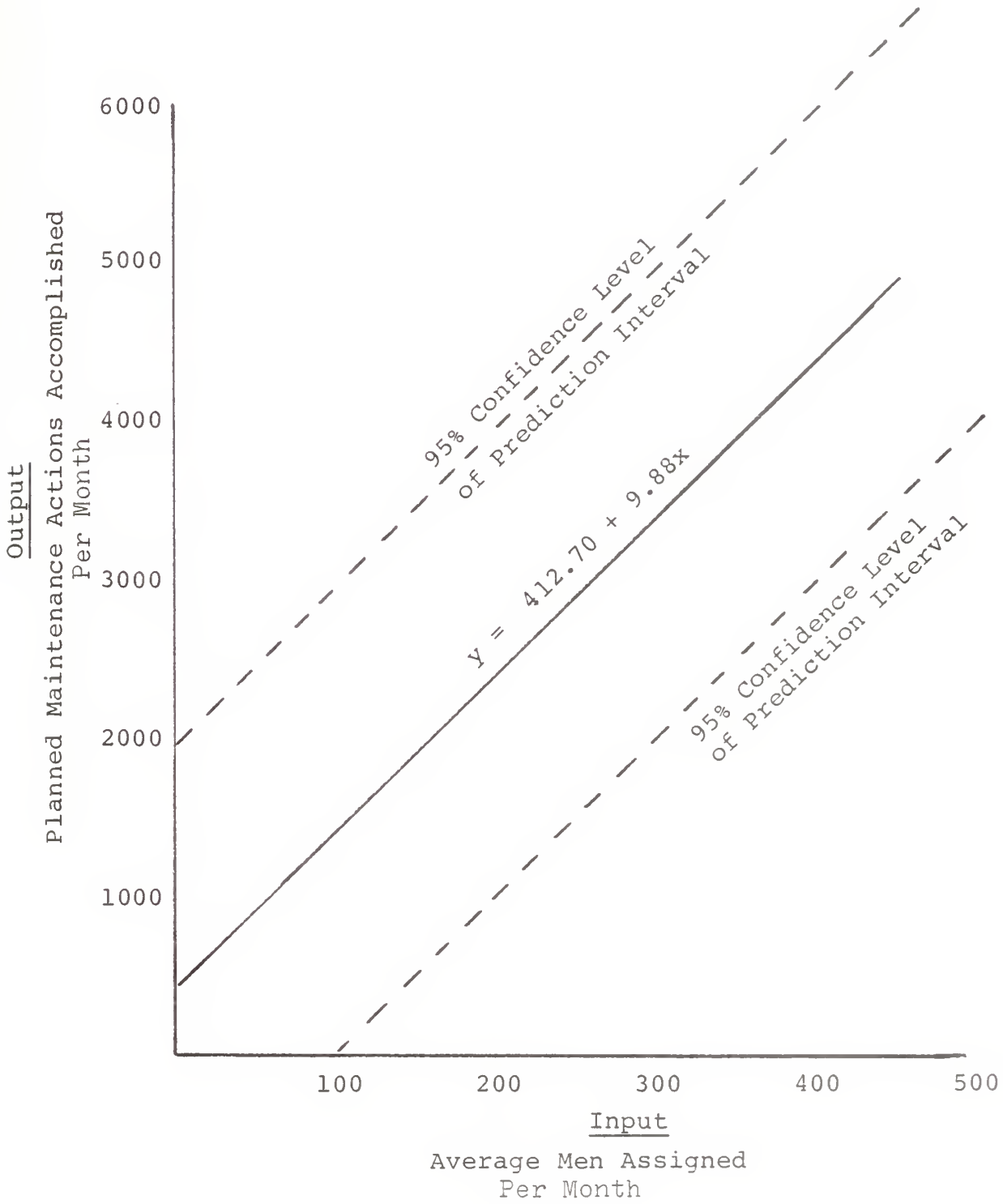
- the level of output of planned maintenance actions accomplished is greatly affected by variables other than input variables such as number of working days in the month, number of holidays, number of underway days, number of planned maintenance actions scheduled, number of equipment casualties requiring corrective maintenance, etc.

2. A Production Function

Once output and input information has been collected for an organization, it is relatively easy to plot and compute production functions. A production shows the relationship between output and input. In this study a production function for the 26 U. S. Navy ships is shown in Figure 13. The regression equation for this production function was computed utilizing a linear regression computer program and verified using a linear regression program on a hand-held programmable calculator.

For this production function, average productivity ratios, a marginal productivity ratio, and elasticity coefficients can be estimated. For the 26 ships in this study the following estimates were calculated:

Figure 13. Production Function of Planned Maintenance Actions Accomplished for 26 U.S. Navy Ships



- (1) Average productivity ratio for a ship with 265 men assigned $= \frac{\text{Output}}{\text{Input}} = \frac{3031 \text{ planned maint actions}}{265 \text{ men assigned}}$
 $= 11.44 \text{ planned maintenance actions per man}$
- (2) Marginal productivity ratio $= \frac{\text{Change in output}}{\text{Change in 1 unit of input}}$
 $= \frac{9.88 \text{ planned maintenance actions}}{1.0 \text{ men assigned}}$
 $= 9.88 \text{ planned maintenance actions per man}$
- (3) Elasticity of output with respect to input $= \frac{\% \text{ change in output}}{1\% \text{ change in input}} = \frac{.88}{1.00}$
 $= .88$

The estimates for the 26 ships in this study indicate for a ship with 265 men assigned, each man accomplished 11.44 planned maintenance actions per month on the average. The addition of one extra man would result in an estimated increase of 9.88 planned maintenance actions accomplished per month.

The elasticity of output with respect to input of .88 indicates that for every one per cent change in the input of average men assigned, there will be a .88 per cent change in the output of planned maintenance actions accomplished.

The regression equation for this production function is linear in the form $y = a + bx$. The regression equation is

$$Y = 412.70 + 9.88X, \text{ where}$$

Y = planned maintenance actions accomplished, and

X = average number of men assigned.

Relevant statistics of this regression equation are as follows:

$$r^2 = .76$$

$$\text{Standard Error of Estimate} = 606.33$$

$$t \text{ statistic} = 8.67$$

$$F \text{ statistic} = 74.88$$

$$n = 26$$

These relevant statistics indicate that the regression equation is a reasonable model to describe the relationship of the data collected on the 26 ships. The r^2 of .76 indicates that 76 per cent of the variation in output can be explained by the variation in the input (average number of men assigned). The Standard Error of Estimate of 606.33 indicates that 95 per cent of all estimates of output will be within plus or minus 1.96 times 606.33 planned maintenance actions accomplished. The t and F statistics indicate that the regression equation and the b coefficient (9.88) are significant and contribute to the explanation of the variation in output. The n of 26 indicates there was one data point for each of the 26 ships.

To test this regression equation, the data for Ship 15 was used to determine how closely the actual number of planned maintenance actions accomplished could be estimated for the average number of men assigned for Ship 15 using the model. Using the model, the estimated number of planned maintenance actions accomplished was 3232.9 with 285.3 average number of men assigned. The actual value for Ship 15

with 285.3 average number of men assigned was 3066.3 planned maintenance actions accomplished. The difference between the estimated value and the actual value was 166.6 planned maintenance actions accomplished which is approximately a five per cent difference.

The production function shown in Figure 13 could be used for sensitivity analysis to answer "what if" questions regarding what would happen to the level of output with various changes in the level of input. For example, what would happen to the level of output if the level of input was changed on Ship 15 from 285 men to 250 men. Using the model, it could be estimated that the output of planned maintenance actions accomplished would drop from approximately 3233 to 2884 actions per month. This would be a decrease of approximately 11 per cent in the number of planned maintenance actions accomplished per month.

This 11 per cent decrease in output of planned maintenance actions accomplished could also be estimated using the computed elasticity coefficient of .88. In this case with Ship 15, the level of input was to be reduced from 285 men to 250 men (12 per cent). The estimated decrease in output could be calculated by multiplying .88 times 12 per cent which equals 11 per cent.

A production function showing the relationship between the output of planned maintenance actions accomplished and the input of amount of OPTAR consumed for repair parts was also computed. However, the relationship between the output and

this input was found to be not strong enough to make accurate estimates of productivity ratios or for sensitivity analysis. The input of average number of men assigned is strongly correlated ($r = .87$) with the output of planned maintenance actions accomplished.¹¹ The input of amount of OPTAR consumed for repair parts is less strongly correlated ($r = .45$) with the output of planned maintenance actions accomplished.

Additionally, it was found that the partial-correlation coefficient showing the relationship between the amount of OPTAR consumed for repair parts and the number of planned maintenance actions accomplished holding the effects of the average number of men assigned constant was .10 which was not statistically significant at the .05 level of significance. This suggests that there is little relationship, if any, between the amount of OPTAR consumed for repair parts and the number of planned maintenance actions accomplished. Additional information on the relationship between output and input on the 26 ships is provided in Appendix J.

3. Productivity Ratios

Utilizing the output and input information collected for the 26 ships in this study, it was possible to directly compute productivity ratios. Two productivity ratios were

¹¹A Pearson correlation coefficient r of $+1.0$ or -1.0 indicates a perfect relationship. A Pearson correlation coefficient r of 0.0 indicates no relationship exists.

computed for each ship. A labor productivity ratio - planned maintenance actions per man was computed. It was computed as follows:

$$\begin{array}{l} \text{Planned} \\ \text{maintenance} \\ \text{actions} \\ \text{per man} \end{array} = \frac{\text{planned maintenance actions accomplished}}{\text{average number of men assigned}}$$

A materials productivity ratio - planned maintenance actions per OPTAR dollar was computed. It was computed as follows:

$$\begin{array}{l} \text{Planned} \\ \text{maintenance} \\ \text{actions per} \\ \text{OPTAR dollar} \end{array} = \frac{\text{planned maintenance actions accomplished}}{\text{amount of OPTAR consumed for repair parts}}$$

Table V displays the productivity ratios for the 26 U. S. Navy ships. In examining this table it can be seen that the average labor productivity ratio is 11.81 planned maintenance actions per man. The average materials productivity ratio is .92 planned maintenance actions per OPTAR dollar.

Frequently it is desirable to examine changes or trends in productivity ratios to determine if productivity is improving or declining. Figure 14 is a time-series plot of the labor productivity ratio planned maintenance actions per man per month for the six month period 1 November 1975 to 30 April 1976. It shows there is substantial changes from month to month. Determination of the reasons for these changes was not accomplished in this study. Determination of reasons why productivity ratios change from month to month is an important aspect of productivity analysis.

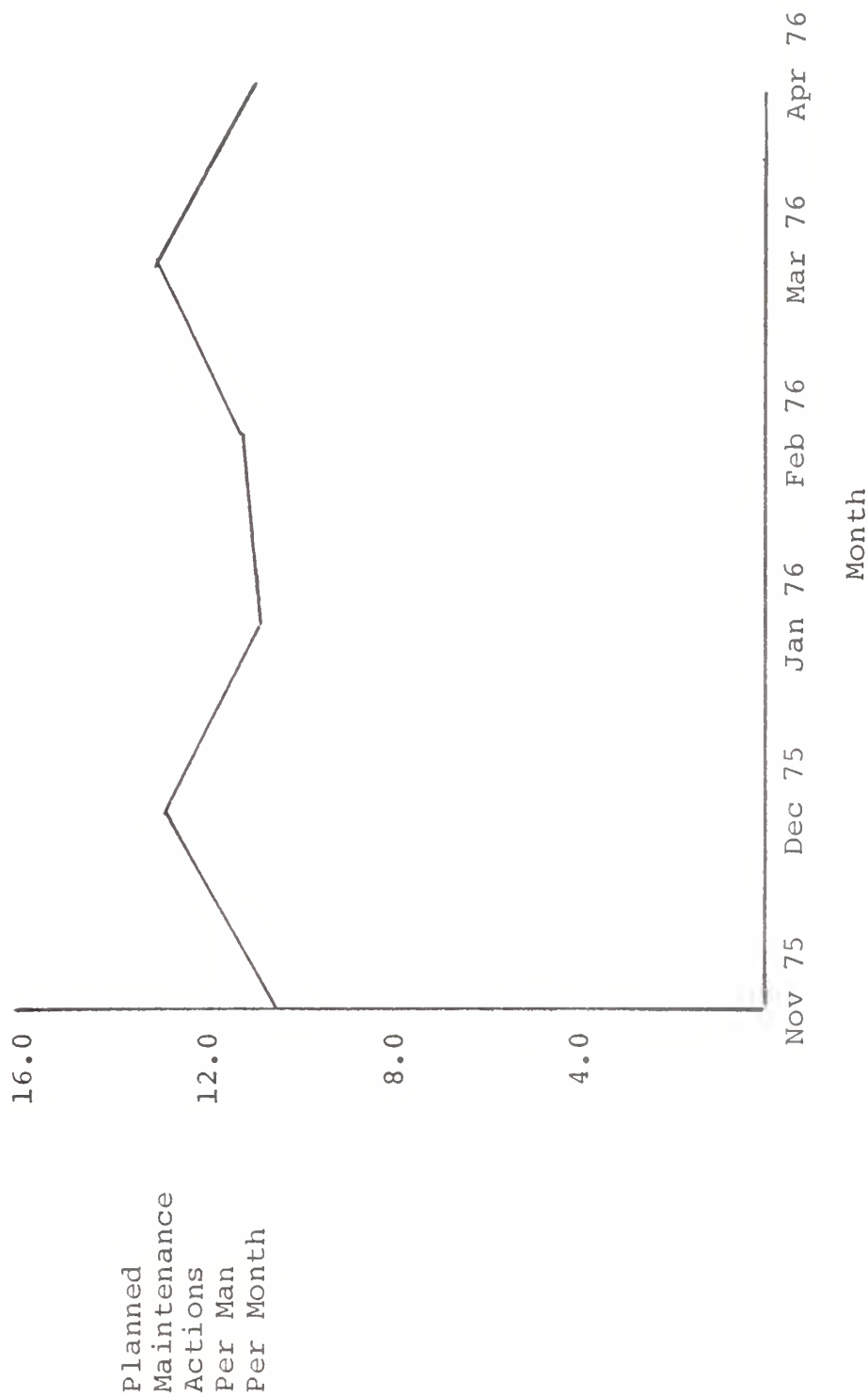
Examination of the data in Table V suggests the following:

Table V. Productivity Ratios for 26 U.S. Navy Ships¹²
(Average per Month)

<u>Ship</u>		<u>Planned Maintenance Actions per Man</u>	<u>Planned Maintenance Actions per OPTAR Dollar</u>
Combatant Type (mean)	11.77		.42
01		10.52	.20
02		11.71	.43
03		11.60	.76
04		10.51	.27
05		12.89	.35
06		11.36	.36
07		12.20	.24
08		13.40	.78
Amphibious Type (mean)	11.48		1.07
09		8.73	.93
10		12.63	1.19
11		8.83	.55
12		10.12	.72
13		12.96	.75
14		10.28	.88
15		10.74	.62
16		11.81	3.81
17		12.07	.41
18		16.58	.85
Service Type (mean)	12.26		1.23
19		15.86	3.10
20		7.06	.54
21		12.17	.95
22		14.23	.45
23		12.63	.88
24		8.88	1.32
25		12.18	1.70
26		15.03	.91
Total (mean)	11.81		.92
Total standard deviation	2.73		1.81

¹²The productivity ratios were computed by averaging six monthly productivity ratios. They were not computed using the data in Table IV.

Figure 14. Planned Maintenance Actions Per Man Per Month for 26 U.S. Navy Ships



(1) Productivity ratios can be computed for U. S. Navy ships once the productivity measure, output measure, and input measure have been defined.

(2) There is substantial variability between the ships in terms of each productivity measure. With the measure planned maintenance actions per man the ratio for the highest ship is more than double the ratio for the lowest ship. For the measure planned maintenance actions per OPTAR dollar the ratio for the highest ship is nearly 20 times the ratio for the lowest ship.

(3) Productivity measures must be used with other management information to be useful in identifying and diagnosing potential problem areas.

(4) A major value of computing the productivity ratios is that they provide an awareness of the relationship between output and input, suggest possible problem areas, and suggest possible favorable or unfavorable trends.

4. Average Cost Ratios

Once output and input information has been collected, average cost ratios can be computed. Average cost ratios are the inverses of productivity ratios. Average cost ratios are computed as follows:

$$\text{Average Cost Ratio} = \frac{\text{Input Measure}}{\text{Output Measure}}$$

In this study three average cost ratios were computed for each of the 26 ships. The following average cost ratios were computed:

- man-hours per planned maintenance action = $\frac{\text{number of man hours expended on planned maintenance actions}}{\text{number of planned maintenance actions accomplished}}$
- OPTAR cost per planned maintenance action = $\frac{\text{amount of OPTAR consumed for repair parts}}{\text{number of planned maintenance actions accomplished}}$
- personnel & repair part costs per planned maint action = $\frac{\text{estimated personnel \& repair part costs}}{\text{number of planned maintenance actions accomplished}}$

These average cost ratios are listed in Table VI.

Examining this table, it can be seen that on the average 1.15 man hours were expended on each planned maintenance action accomplished, \$2.34 was spent for repair parts for each planned maintenance action accomplished, and there was an estimated \$92.11 in personnel and repair part costs for each planned maintenance action accomplished. The average cost ratios are listed to demonstrate how average cost ratios can be computed with output and input information on U. S. Navy ships.

Examination of the data in Table VI suggests the following:

- (1) There is substantial variability between ships.
- (2) When computing estimated personnel costs and OPTAR costs for repair parts, estimated personnel costs are approximately 40 times the OPTAR costs for repair parts.
- (3) Average cost ratios can be easily computed and understood.
- (4) One of the principal values of average cost ratios is the same as productivity ratios - they provide an awareness of the relationship between output and input.

Table VI. Average Cost Ratios for 26 U. S. Navy Ships
(Average per Month)

Ship	Man-hours Per Planned Maintenance Action	OPTAR Cost Per Planned Maintenance Action	Personnel & Repair Part Costs per Planned Maint Action ¹³
Combatant Type (mean)	1.23	\$3.71	\$90.89
01	1.13	5.82	102.50
02	1.45	2.44	88.37
03	1.52	3.66	91.97
04	1.48	4.10	103.91
05	1.11	3.20	81.37
06	1.08	3.28	94.03
07	1.30	4.35	87.14
08	.75	2.80	77.80
Amphibious Type (mean)	1.15	\$1.85	\$94.51
09	.99	1.49	121.29
10	1.06	1.07	87.85
11	1.07	2.05	116.37
12	1.89	1.98	104.09
13	.87	1.84	80.39
14	1.40	1.69	101.04
15	1.11	2.57	96.36
16	.91	1.09	86.96
17	1.19	2.98	88.51
18	.99	1.70	62.22
Service Type (mean)	1.08	\$1.58	\$90.34
19	.64	1.01	64.60
20	1.79	2.03	145.62
21	.96	1.27	83.96
22	.95	2.84	76.13
23	1.02	1.32	81.31
24	1.41	1.33	117.25
25	.89	1.06	83.98
26	.97	1.83	69.86
Total (mean)	1.15	\$2.34	\$92.11
Total Standard deviation	.39	1.73	23.50

¹³MPN personnel costs were estimated by multiplying the average number of men assigned per month by \$1000.

C. DIFFERENCES BETWEEN HIGH AND LOW PRODUCTIVITY SHIPS

In this study the 26 ships were divided into two groups according to their productivity ratios. The ships with above average labor productivity ratios planned maintenance actions per man were designated high productivity ships. The ships with below average labor productivity ratios planned maintenance actions per man were designated low productivity ships. Differences between the two groups of ships were examined to determine if the productivity measurement was accurate and valid and to isolate factors related to levels of productivity on U. S. Navy ships.

In examining the differences between the high and low productivity ships, three steps were followed. First, the high and low productivity ships were compared in terms of three productivity ratios: planned maintenance actions per man, planned maintenance actions per OPTAR dollar, and planned maintenance actions per man-hour. Second, the high and low productivity ships were compared in terms of PMS accomplishment rate, PMS inspection scores, number of major awards won, and number of departmental awards won. Third, the high and low productivity ships were compared in terms of enlisted personnel attitudes as measured by the Ship Efficiency Questionnaire shown in Appendix A.

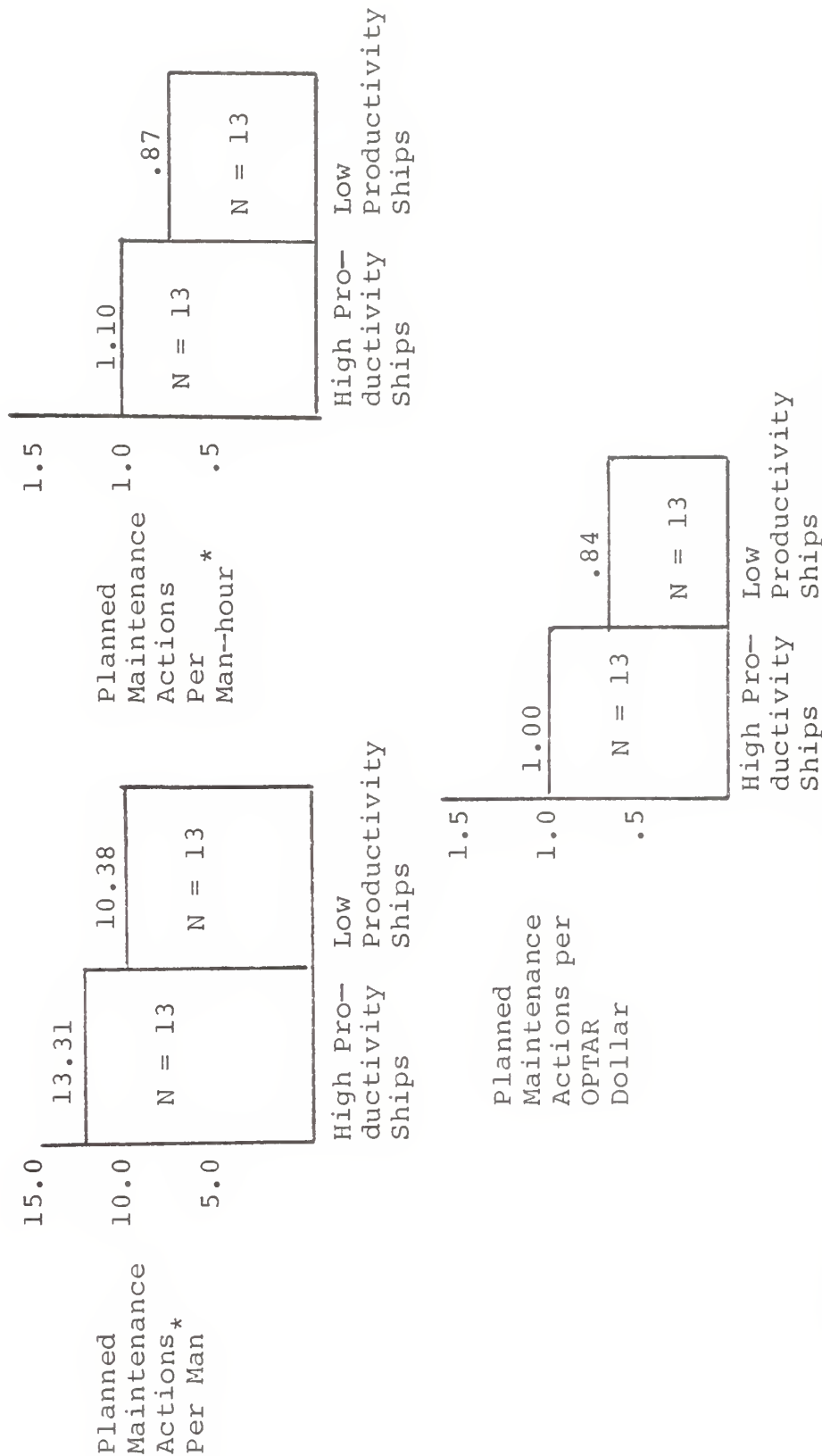
1. Differences in Productivity Ratios

In terms of productivity ratios, the high productivity ships had higher average productivity ratios than the low productivity ships. The high productivity ships had a

higher average planned maintenance actions per man, planned maintenance actions per OPTAR dollar, and planned maintenance actions per man-hour than the low productivity ships. Figure 15 displays the differences in these productivity ratios between the two groups of ships.

In examining these differences it has to be determined if these differences were true differences or merely the result of a chance occurrence. To determine if these differences were true differences, the statistical t-test was used to test the differences in the mean productivity ratios between the high and low productivity ships. It was found that the differences between the high and low productivity ships were statistically significant at the .05 level of significance for planned maintenance actions per man and for planned maintenance actions per man-hour. This indicates that there is at least a 95 per cent chance that the differences are true differences. There is less than a 5 per cent chance that the differences are due to a chance occurrence. It was found that the difference between the high and low productivity ships was not statistically significant at the .05 level of significance for planned maintenance actions per OPTAR dollar. This suggests that there may not be a true difference between the high and low productivity ships in terms of the productivity ratio planned maintenance actions per OPTAR dollar.

Figure 15. Differences in High and Low Productivity Ships in Terms of Productivity Ratios



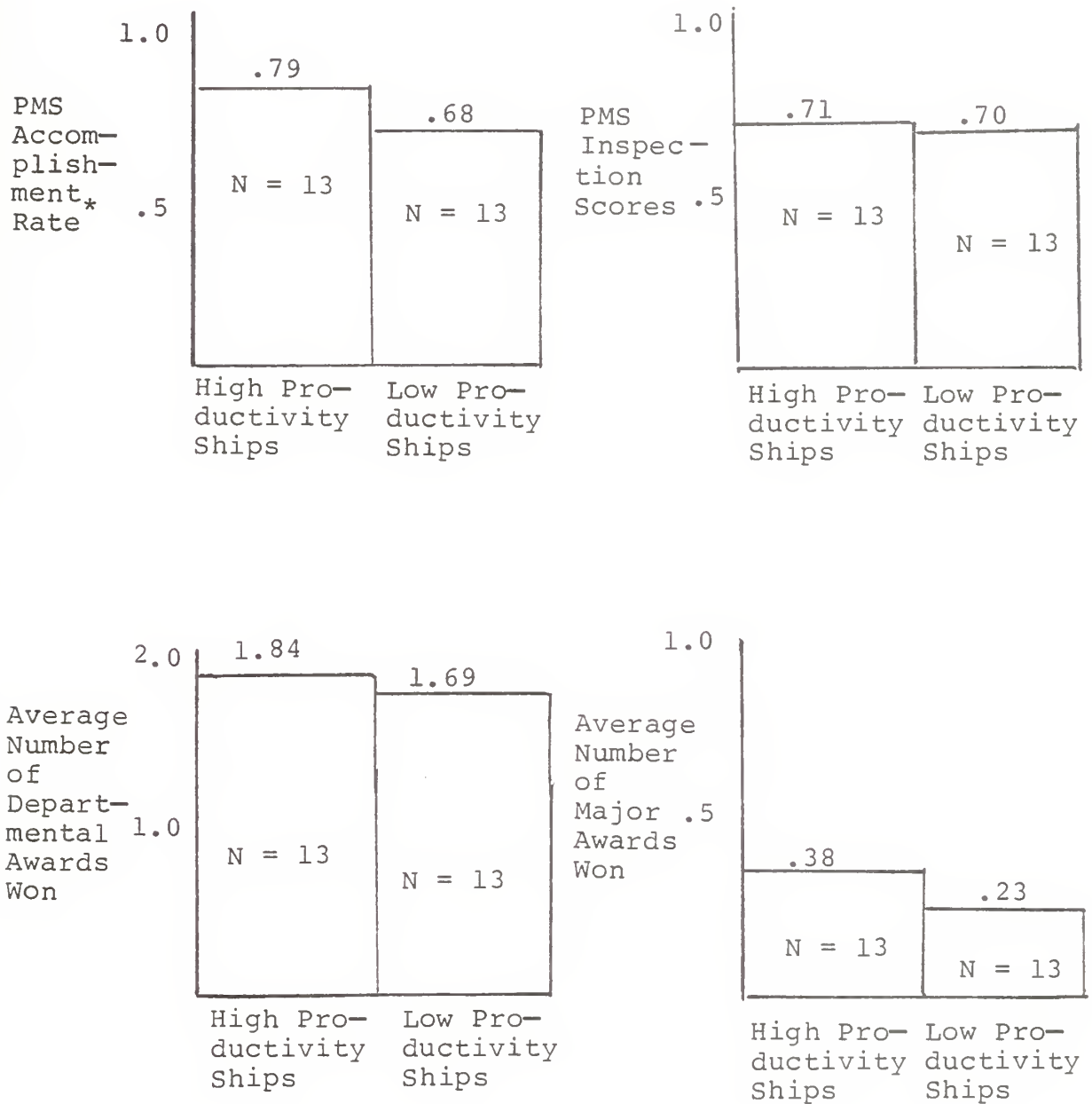
*Differences statistically significant at .05 level of significance.
N = number of ships.

2. Differences in Other Performance Ratios

Next, the high and low productivity ships were compared in terms of other performance data. The high productivity ships had a higher average PMS accomplishment rate, a higher average PMS inspection score, a higher average number of major awards won, and a higher average number of departmental awards won.¹⁴ Figure 16 displays the differences in these performance measures between the high and low productivity ships. It was found that the difference between the high and low productivity ships in terms of PMS accomplishment rate was statistically significant at the .05 level of significance. This suggests that there are true differences between the high and low productivity ships in terms of PMS accomplishment rate. It was found that the differences between the high and low productivity ships were not statistically significant at the .05 level of significance for PMS inspection scores, number of major awards won, and number of departmental awards won. This suggests that there are not true differences between the high and low productivity ships in terms of PMS inspection scores, number of major awards won, and number of departmental awards won.

¹⁴ Additionally, C-rating data on the material readiness of the ships was collected by systematic sampling of NAVFORSTAT reports. The high productivity ships had a slightly higher average per cent of days in the two highest categories of material readiness. However, the difference between the high and low productivity ships was not statistically significant at the .05 level of significance.

Figure 16. Differences in High and Low Productivity Ships in Terms of Performance Measures



* Differences statistically significant at .05 level of significance. Planned maintenance actions per man was found to be positively correlated ($r = .70$) with PMS accomplishment rate. N = number of ships.

The differences between the high and low productivity ships in terms of productivity ratios and performance measures such as PMS accomplishment rate suggest the following:

(1) High productivity ships as determined by the labor productivity measure planned maintenance actions per man appear, in general, to be superior to the low productivity ships in terms of the productivity and performance measures examined in this study.

(2) The productivity measure planned maintenance actions per man appears to be a reasonably accurate and valid labor productivity measure.

(3) The materials productivity measure planned maintenance actions per OPTAR dollar appears to be less accurate, less valid, and less meaningful than the labor productivity measure planned maintenance actions per man.

3. Differences in Enlisted Personnel Attitudes and Perceptions

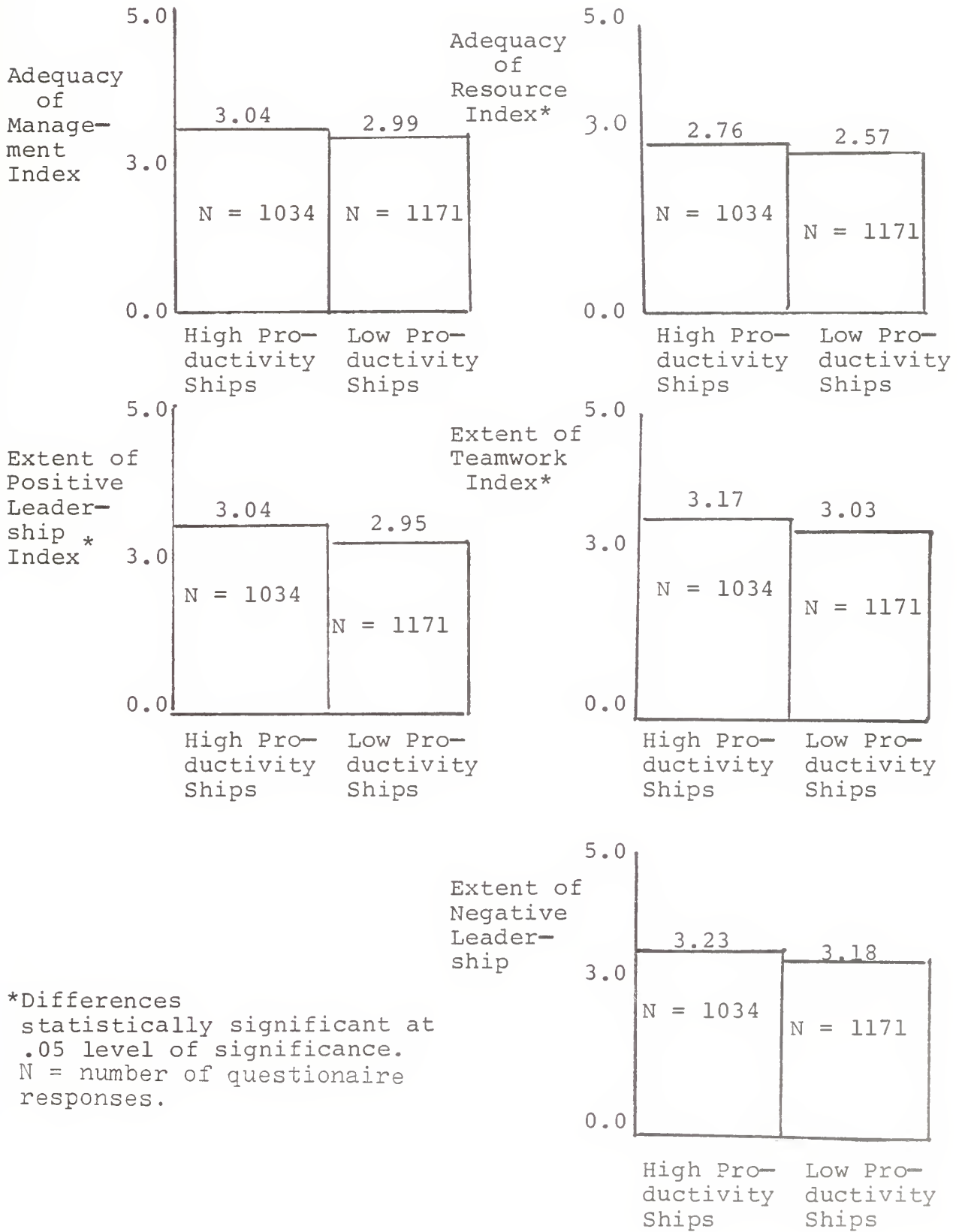
Lastly, the high and low productivity ships were compared in terms of the attitudes and perceptions of the enlisted personnel on the ships. This was done by comparing the responses of the personnel from the Ship Efficiency Questionnaire. The questionnaire was designed to measure attitudes and perceptions of enlisted personnel regarding factors which may affect productivity such as adequacy of tools. A total of 2212 enlisted personnel responded to the questionnaire. Approximately one half of the respondents were from high productivity ships and approximately one half of the respondents were from low productivity ships. The purpose in comparing

the responses from personnel on the high and low productivity ships was to identify factors related to productivity levels on the ships. Identification of factors related to productivity levels could lead to a better understanding and explanation of why some ships have higher productivity ratios than other ships.

In this study it was found that enlisted personnel on the high and low productivity ships have consistent differences in terms of attitudes and perceptions. Figure 17 displays the mean score on each of the five indices measured by the Ship Efficiency Questionnaire of enlisted personnel on the high and low productivity ships. The index scores are on a scale of one to five.¹⁵ A higher score indicates a more positive attitude or perception concerning the factor being measured. On each of the indices the personnel on the high productivity ships had a higher mean index score. This indicates that the personnel on the high productivity ships had a more positive attitude toward the factor being measured by the index than the personnel on the low productivity ships. Personnel on the high productivity ships had a higher mean index score on the adequacy of management index, the adequacy of resources index, the extent of positive leadership index, and the extent of negative leadership index. It should be noted that the differences in the mean index scores were

¹⁵The Likert Scale was used in the Ship Efficiency Questionnaire: 1 - to a very little extent, 2 - to a little extent, 3 - to some extent, 4 - to a great extent, 5 - to a very great extent.

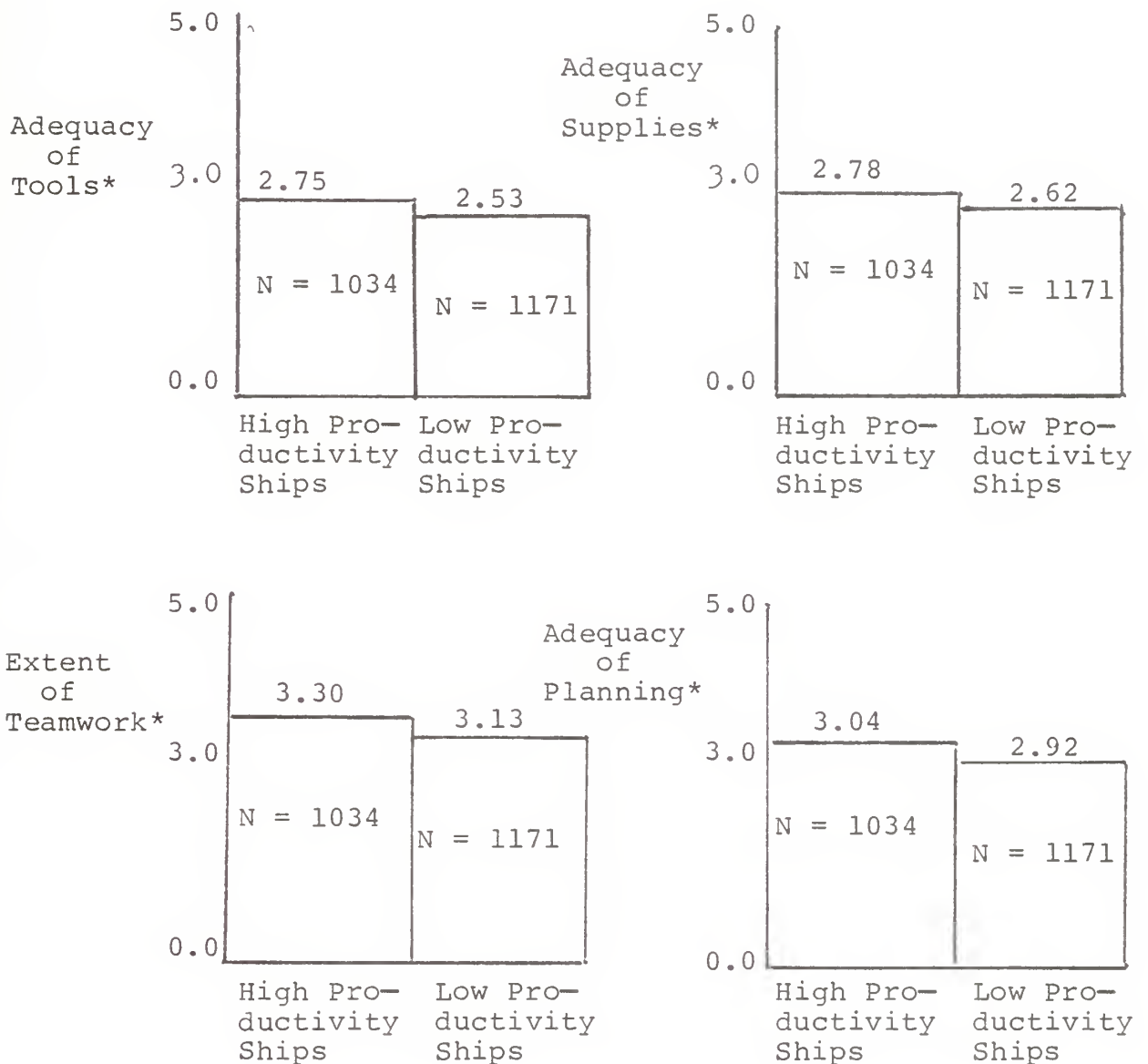
Figure 17. Differences in High and Low Productivity Ships in Terms of Questionnaire Index Scores



statistically significant for the adequacy of resources index, the extent of positive leadership index, and the extent of teamwork index at the .05 level of significance. This suggests that there are true differences between the attitudes and perceptions of the personnel on the high and low productivity ships in terms of their attitudes and perceptions regarding the adequacy of the resources they use such as tools and supplies, the extent of positive leadership such as use of praise they feel they receive, and the extent of teamwork they feel their work center has. It should be noted that the differences in the mean index scores were not statistically significant for the adequacy of management index and the extent of negative leadership index at the .05 level of significance. This suggests that the observed differences between these index scores may be the result of chance rather than the result of true differences for these two indices.

In examining the mean scores per question from personnel on the high and low productivity ships, it was found that there were differences between the responses from personnel on the high and low productivity ships. Figure 18 displays the mean response per question for personnel on the high and low productivity ships for four questions. The personnel on the high productivity ships had a higher mean score on each of the 16 questions except for one question. Only on the question dealing with the effectiveness of shipboard training did the personnel on the low productivity ships have a higher mean score. It should be noted that the differences between

Figure 18. Differences in High and Low Productivity Ships in Terms of Questionnaire Results



* Differences statistically significant at .05 level of significance. N = number of questionnaire responses.

the mean scores per question were statistically significant at the .05 level of significance for seven out of the 16 questions. It appears that there were true differences between personnel on the high and low productivity ships in terms of their attitudes and perception regarding the adequacy of their tools, the adequacy of their supplies, the extent supervisors assist them, the extent they are motivated to work, the extent of teamwork in their work center, the extent of effective planning in their work center, and the extent of encouragement in their work center.

The responses to the four questions in Figure 18 have the highest degree of association with the level of productivity on the 26 U. S. Navy ships. The degree of association is indicated by the correlation coefficients listed below:

- adequacy of tools (r = .67),
- adequacy of supplies (r = .55),
- extent of teamwork (r = .54),
- adequacy of planning (r = .47).

The correlation coefficients in parentheses are significant at the .05 level of significance. Other correlation coefficients are listed in Appendix B.

In summary, there appears to be four major factors which are related to the level of labor productivity on the 26 ships in this study. These factors in the order of their importance are:

- (1) adequacy of tools,
- (2) adequacy of supplies,

- (3) extent of teamwork,
- (4) adequacy of planning.

Both the examination of the differences in the attitudes and perceptions of enlisted personnel on the high and low productivity ships and the examination of the relationships between the levels of productivity and the responses to the Ship Efficiency Questionnaire suggest the importance of these four factors. It would appear that commanding officers interested in improving the level of labor productivity on their ships should implement management actions oriented to improve these four factors on their ships.

D. RESULTS OF THE STUDY

In this study with 26 U. S. Navy ships, the following are the principal results and findings:

- (1) Labor and material productivity ratios were computed for 26 U. S. Navy ships. This indicates that productivity can be measured on U. S. Navy ships.
- (2) The output measure used in this study was planned maintenance actions accomplished. This appears to be a reasonable output measure for U. S. Navy ships. It was found that the average number of men assigned is significantly more important than the amount of OPTAR consumed for repair parts in affecting the number of planned maintenance actions accomplished.
- (3) Of the 26 ships in this study, the ships with above average labor productivity ratios in terms of planned maintenance actions per man also had other above average productivity ratios and had above average PMS accomplishment rates.

(4) After examining differences in attitudes and perceptions of enlisted personnel on high and low productivity ships, the following factors appear to be related to the level of productivity on the ships: adequacy of tools, adequacy of supplies, extent of teamwork, and adequacy of planning.

V. CONCLUSION

A. FINDINGS AND RECOMMENDATIONS

The following are the findings of this research project on measuring and enhancing productivity on U. S. Navy ships:

(1) Within the U.S. Federal Government there are substantial efforts being directed toward productivity measurement and enhancement in federal agencies.

(2) An appropriate output measure for U. S. Navy ships is planned maintenance actions accomplished. Planned maintenance actions accomplished are the sum of all MR's (maintenance requirements as defined in the 3M/PMS System) fully accomplished and 1/2 of all MR's partially accomplished. With this output measure production functions can be computed, average and marginal productivity ratios can be computed, and elasticity coefficients can be computed.

(3) Once an output measure has been defined, productivity can be measured on U. S. Navy ships. Productivity ratios can be computed by dividing the output measure by an appropriate input measure.

(4) There is no clearly defined and accepted output measure for U. S. Navy ships. However, input measures such as number of men assigned to a ship or amount of OPTAR consumed are clearly defined and measured on U. S. Navy ships.

(5) The productivity measure planned maintenance actions per man was computed for 26 U. S. Navy ships. This productivity

measure is considered a useful and valid performance measure for U. S. Navy ships.

(6) The productivity measure planned maintenance actions per OPTAR dollar (for repair parts) was computed for 26 U. S. Navy ships. It is considered an inferior measure to planned maintenance actions per man.

(7) In terms of affecting the level of output of planned maintenance actions accomplished, the level of personnel resources (men assigned) is significantly more important than the level of OPTAR dollars consumed for repair parts.

(8) Of the 26 U. S. Navy ships studied, the ships with the high labor productivity ratios of planned maintenance actions per man tended to have high PMS accomplishment rates.

(9) The methodology of "how to design and implement a productivity measurement and enhancement program" used in this research is applicable to U. S. Navy ships and in general to all organizations. The methodology includes the following steps to design and implement a productivity measurement system:

- define suitable input and output measures,
- define suitable productivity measures,
- measure the levels of input and output using the input and output measures,
- compute productivity ratios,
- define suitable formats for productivity reports.

The methodology includes the following steps to enhance or improve the productivity of the organization:

- define weaknesses and opportunities in the organization for productivity improvement,

- gather information throughout the organization on weaknesses and opportunities through personnel interviews, through attitude surveys, through brainstorming, etc.,

- implement management changes or policies in improving technology used in the organization, improving capital equipment (tools, machinery, etc.), and creating more favorable attitudes through leadership style changes, better communication, more explicit and well-known objectives, better handling of grievances, and better support for organization members, etc.,

- determine if the management changes and policies have improved productivity.

For a productivity measurement and enhancement program to be successful and to favorably impact an accomplishment of the organization's objectives with the least expenditure of resources the following should be present in the organization:

- commitment to the productivity program at all levels,
- involvement of personnel in the productivity program at all levels,
- incentives for productivity improvement,
- clearly stated goals and objectives for the productivity program,
- analytical capability in the organization,
- a measurement and reporting system in the organization,
- periodic evaluation of the productivity program.

(10) The Efficiency Questionnaire shown in Appendix A is considered a valid instrument to measure attitudes and perceptions of enlisted men aboard U. S. Navy ships regarding factors related to productivity levels on U. S. Navy ships.

Responses from 2212 enlisted personnel to this questionnaire indicate that the following factors appear to be related to the level of productivity on the ships: adequacy of tools, adequacy of supplies, extent of teamwork, and adequacy of planning.

(11) The Ship Productivity Report shown in Appendix C is considered a feasible and usable report format for general use for U. S. Navy ships.

(12) The Shipboard Productivity Improvement Program outlined in Appendix A is considered a feasible and useful productivity measurement and enhancement program for U. S. Navy ships.

The following are the recommendations of this author based upon the findings and conclusions of this research project on measuring and enhancing productivity on U. S. Navy ships. These include recommendations for further research.

(1) There should be a U. S. Navy Productivity Information Service organized. Its purpose would be to provide commands with suggestions, articles, and other information on productivity measurement and enhancement. The service would maintain liaison with the federal agencies involved in productivity measurement and enhancement.

(2) There should be flag officer advisory committee to set Navy-wide policies for the Department of the Navy Productivity

Program. Such a committee could provide visible, top-level commitment to the productivity program.

(3) The OPNAV instruction regarding the Department of the Navy Productivity Program should include the following:

- the designation of an output measure for U. S. Navy ships,
- a suggested productivity measurement and enhancement program for U. S. Navy ships similar to the program outlined in Appendix A,
- encouragement for the use of productivity ratios on U. S. Navy ships.

(4) The U. S. Navy Human Resources Management Program should have as one of its major objectives "the improvement of productivity on U. S. Navy ships." Questions in the Ship Efficiency Questionnaire shown in Appendix A should be evaluated for possible inclusion in the U. S. Navy Human Resources Management Survey. A Productivity Index should be incorporated into the Human Resources Management Survey. The following two questions could be added to the HRM Survey to form the Productivity Index:

- To what extent do you have adequate tools to work efficiently?
- To what extent do you have adequate supplies to work efficiently?

(5) The Office of Naval Research, the Office of the Chief of Naval Operations (OP 01), and the Naval Postgraduate School should have a vigorous productivity research program similar

to the National Foundation of Science Program. One aspect of that program is shown in Appendix G. The productivity research program should address the following potential research topics:

- Do U. S. Navy ships have adequate tools?
- What is the most suitable output measure for U. S. Navy ships?
- Is a fleet-wide productivity measurement and enhancement program desirable?
- How is the degree of capitalization on a ship measured and are U. S. Navy ships adequately capitalized? The degree of capitalization could be thought of as the amount of tools and equipment that are "used but not used up" during work.
- What is the impact of productivity information when it is fed-back to shipboard personnel?
- What is the effect of teamwork in achieving a high level of productivity?
- What is the most suitable productivity measure for U. S. Navy ships?
- What are the appropriate weights for a productivity measure? For example, if planned maintenance actions per man is a suitable productivity measure, how should different MR's (Maintenance Requirements) be weighted to compute productivity ratios?
- What is the effect of personnel policies which encourage motivation, creativity, innovation, and identification with organization goals on productivity levels?

- What is the relationship of human factors indicators of unauthorized absence rate, divorce rate, non-judicial punishment rate, and reenlistment rate on productivity levels?

- What personnel management policies are highly related to productivity levels?

(6) Productivity measurement and enhancement programs and methodologies should be taught and discussed in both officer and enlisted management education and training courses under the auspices of the Chief of Naval Education. At the Naval Postgraduate School, the Naval War College, and the Armed Forces Services College the following are recommended:

- establishment of a productivity library,
- continuous receipt of productivity newsletters and publications from federal agencies such as the Joint Financial Management Improvement Program, Department of Commerce, Civil Service Commission, Department of Labor, Department of Defense, and the Department of the Navy,
- seminars be conducted with speakers from the above mentioned organizations,
- productivity topics be included in courses in general management, personnel management, financial management, management information systems, management policy, etc.,
- students be encouraged to do research papers and independent research on productivity topics.

B. SUMMARY

In summary, the conclusion of this research project is that productivity measurement is feasible for U. S. Navy ships. The following is a brief summary of the research objectives and findings in this research project on productivity measurement and enhancement on U. S. Navy ships:

Research Objective

1. Apply methodology of productivity measurement presently used in private industry and U.S. Federal agencies to U.S. Navy ships.
2. Define output and productivity measures for U.S. Navy ships.
3. Compute a production function showing the relationship between output and input measures for U.S. Navy ships.
4. Develop and administer an attitude questionnaire to determine what factors are related to productivity on U.S. Navy ships.

Research Finding

Productivity can be measured on U.S. Navy ships once an output measure such as planned maintenance actions accomplished has been clearly defined. Productivity was measured on 26 U.S. Navy ships in this research project.

One output measure (planned maintenance actions accomplished), a labor productivity measure (planned maintenance actions per man), and a materials productivity measure (planned maintenance actions per OPTAR dollar) were defined and utilized in this research project. These measures can be used for U.S. Navy ships.

A production function for 26 U.S. Navy ships was computed. The average number of men assigned was found to be significantly more important than the amount of OPTAR spent for repair parts in affecting the number of planned maintenance actions accomplished.

The Ship Efficiency Questionnaire shown in Appendix A was developed at the Naval Postgraduate School and administered to 2212 enlisted personnel. The questionnaire consists of 16 questions and is considered a valid attitude measurement instrument which can be used aboard U.S. Navy ships.

5. Isolate factors which are related to productivity levels on U.S. Navy ships.

After analyzing the 2212 responses to the Ship Efficiency Questionnaire it was found that four principal factors related to productivity levels on 26 U.S. Navy ships are adequacy of tools, adequacy of supplies, extent of teamwork, and adequacy of planning.

6. Develop a productivity report for U.S. Navy ships similar to productivity reports being used in private industry and U.S. Federal agencies.

Numerous productivity reports were developed and evaluated during this research project. The Ship Productivity Report shown in Appendix C is a format for a computer-based productivity report. The report is considered usable for U.S. Navy ships and within the current "state of the art" for management information systems.

7. Develop a shipboard productivity measurement and enhancement program.

The Shipboard Productivity Improvement Program shown in Appendix A was developed as an end-product of this research project. The program is presented in a U.S. Navy instruction form and outlines suggested steps in implementing a productivity measurement and enhancement program aboard a U.S. Navy ship.

Productivity measurement is feasible on U.S. Navy ships only if the following conditions are met:

- an output measure such as planned maintenance actions accomplished or units of combat readiness is clearly defined,
- productivity measures (output versus input) are clearly defined,
- the value of the productivity information is considered to outweigh the cost of collecting the required data,
- a motivation exists to utilize productivity information to aid in making management decisions.

Many private industries and U.S. Federal government agencies vigorously pursue productivity measurement and enhancement programs. Whether productivity measurement programs are implemented on individual U.S. Navy ships is strictly the decision of the individual commanding officer. He is in the best position to evaluate the potential benefits and costs of a productivity measurement and enhancement program for his ship.

APPENDIX A: SHIPBOARD PRODUCTIVITY
IMPROVEMENT PROGRAM

From: Commanding Officer, USS XXXXXXXXXXXX

To: Distribution List

Subj: Shipboard Productivity Improvement Program

Ref: (a) DODINST 5010.34 of 4 AUG 1975

Encl: (1) Factors Affecting Shipboard Productivity

(2) Sample Productivity Data Record

(3) Sample Productivity Data Worksheet

(4) Sample Format of Productivity Status Board

(5) Sample Ship Efficiency Questionnaire

(6) Mean Scores on Efficiency Questionnaire

1. Purpose. The purpose of this instruction is to provide information on the Shipboard Productivity Improvement Program.

2. Background. For many years there has been considerable interest throughout the Federal government in improving productivity in the Federal government. Reference (a) is the basic instruction in the Department of Defense. Reference (a) discusses productivity enhancement, measurement, and evaluation - operating guidelines and reporting instructions for the Department of Defense. Reference (a) states,

"Organizations must be both (a) effective - accomplish the right things, in the right quantities at the right times and (b) efficient - accomplish the right things with the lowest possible expenditure of resources. The efficiency with which organizations utilize all types of fund resources (operating and investment) to accomplish their mission represents total resource productivity. The efficiency with which organizations utilize labor resources to

accomplish their mission represents labor productivity... The primary objective of the DOD Productivity Program is to achieve optimum growth (increase the amount of goods produced or services rendered in relation to the amount of resources expended) throughout the Department of Defense. Productivity increases are vitally needed to help offset increased personnel costs, free funds for other priority requirements, and reduce the unit cost of necessary goods and services."

3. Discussion. The Shipboard Productivity Improvement Program is a series of objectives, guidelines, and suggestions on how productivity can be measured and improved aboard a U. S. Navy ship. The objective of the program is to improve shipboard productivity in terms of increasing output (accomplishment of PMS) without increasing input of resources (men and materials). It is designed to have a favorable impact on the important shipboard objectives of increasing PMS accomplishment rates, increasing the "productive work hours per day" of shipboard personnel, and improving ship material condition.

The major objective of any ship is to maintain a high state of combat readiness. The material condition of the ship is a major factor affecting the combat readiness of the ship. As shown in enclosure (1) productivity is a key factor affecting the material condition of a ship and consequently the combat readiness of the ship.

Productivity is defined as the ratio of output to input. In this instruction the terms productivity and efficiency are used interchangeably. Productivity indices are ratios of output measures to input measures. There are two productivity indices which can be easily computed for a U. S. Navy

ship. These are the Personnel Productivity Index (PPI) and the OPTAR Productivity Index (OPI). The output measure should be a measure of combat readiness, material condition, or maintenance accomplished. The measure which is easiest to determine is PMS actions completed. Either a weighted index which takes into account the differences between daily, weekly, monthly, semi-annual, etc. maintenance actions or an unweighted index could be used. An unweighted index would be a count of maintenance actions completed. For example, a work center which completed 100 maintenance actions in a week with 10 men assigned and spent \$100 in OPTAR for supplies or repair parts would have the following indices:

Personnel	
Productivity = $100/10 = 10.0$	Maintenance Actions
Index (PPI)	Per Man

OPTAR	
Productivity = $100/100 = 1.0$	Maintenance Actions
Index (OPI)	Per OPTAR \$

The productivity indices can be modified to include non-PMS outputs such as training outputs (example PQS points), service outputs (example meals cooked), and administrative outputs (example letters typed).

There are seven basic steps in implementing a shipboard productivity improvement program. The program can be implemented in one or all departments of a ship. The program can be implemented in one or all work centers of a department. Specific program procedures should be tailored to specific ship, department, and work center needs. The following steps in implementing a program for a shipboard department are suggested:

Step 1. Ensure commitment. There must be a real commitment of the department head, division officers, departmental 3M coordinator, and work center supervisors to the productivity improvement program. The commitment must be for "long-term" productivity gains as opposed to "short-term" productivity gains.

Step 2. Ensure involvement. There must be involvement and participation from men from all levels of the department in planning the specifics of the productivity improvement program.

Step 3. State goals and objectives. The goals and objectives of the program must be fully defined and understood by everyone in the department. The objective of the program is to improve productivity in each participating work center by increasing the output of the work center in terms of maintenance actions accomplished with little or no increase in the input - amount of resources utilized (manhours and/or materials). The objective for each work center is to improve past productivity indices by eliminating inefficiencies, by improving technical skills of work center personnel, by purchasing labor-saving tools and equipment, by improving work center morale, etc. For example a work center which had a PPI of 10.0 maintenance actions per man and an OPI of 1.0 maintenance actions per OPTAR \$ in one month would have the objective of improving their PPI and OPI in the following month.

Step 4. Measure and monitor productivity. There must be a system to measure and monitor productivity and productivity

changes. The output measures, input measures, and productivity indices must be defined. Assuming the output measure of maintenance actions accomplished, the input measure of average men assigned, and the productivity indices of PPI and OPI are selected, the following steps would be followed in the collection of data and the computation of the productivity indices:

4a) Each work center supervisor on Friday afternoon or Monday morning should review the PMS Work Center Weekly Schedule. Each should record the following information on the Productivity Data Record page in his PMS Work Center Manual as shown in enclosure (2):

(1) Dates shown on the weekly schedule.

(2) Number of PM's (Planned Maintenance Actions) scheduled for the week.

(3) Number of PM's fully accomplished during the week.

(4) Number of PM's partially accomplished during the week.

4b) The department 3M coordinator at the end of each month should fill in the Productivity Data Worksheet (enclosure 3). He should do the following:

(1) Review each work center space manual and record the information on the Productivity Data Record page,

(2) Contact the personnel office to determine the average number of enlisted men assigned to each work center for the previous month (the average would equal the number assigned on the first day of the month plus the number assigned on the last day of the month divided by 2),

(3) Contact the supply department to determine the amount of OPTAR which each work center spent during the month (this amount would equal the value of all the NAVSUP FORMS 1250's submitted by each work center during the previous month),

(4) Fill out the remaining sections of the Productivity Data Worksheet (note that a partially accomplished PM equals 1/2 of a fully accomplished PM),

(5) Submit the completed Productivity Data Worksheet to the department head with copies to division officers and work center supervisors.

4c) The department head should meet with division officers, the departmental 3M coordinator, and other key personnel to discuss the productivity results of the previous month and productivity objectives for the current month. Key questions which might be addressed are:

(1) Is this data correct? Does it support subjective evaluations in each work center?

(2) What can be done to improve productivity in the current month?

(3) What is the minimum productivity we should be striving for in the current month given the output requirements (number of PM's which should be accomplished) and the availability of inputs (personnel and OPTAR)?

(4) Do we need additional resources?

4d) The department head should maintain a Productivity Status Board in the department office or some other suitable location. A suggested format for the Productivity Status

Board is shown in enclosure (4). The purpose of the status board would be to show productivity trends and to provide a feedback to work center personnel on their productivity performance.

Step 5. Provide incentives. There should be incentives provided for work center personnel to make a concerted effort to improve productivity. Incentives could include granting of extra liberty, awarding high evaluation marks, recommendations for Commanding Officer's Meritorious Mast, recommendations for special awards, etc.

Step 6. Have analytic capability. There should be analysis of the productivity data to discover problem areas and unfavorable trends. Attitudes affecting productivity should be investigated. Enclosure (5) is a sample efficiency questionnaire which can be used to investigate attitudes of work center personnel. Enclosure (6) lists mean scores on each question from 2212 respondents who took the questionnaire in 1976.

Step 7. Periodically evaluate the program. There should be a set procedure to periodically evaluate the entire productivity improvement program. This is to determine if the program is meeting its stated objectives, if the data collection is worth the time involved, if the program is favorably affecting the attitudes of work center personnel, if the program is favorably affecting PMS accomplishment, and if the program is favorably affecting the material condition of work center equipment. If the program is having an overall

favorable effect, it should be continued. If the program is having an overall unfavorable effect, it should be discontinued.

Implementation of a productivity improvement program can produce many favorable effects. Some of these are:

(a) The program can result in greater accomplishment of PMS and therefore improve the material condition of the ship.

(b) The program can result in a decrease in the consumption of resources. Jobs could be done with fewer personnel and less expenditure of OPTAR funds.

(c) The program can result in increased motivation of work center personnel to be efficient and to be less wasteful of time, material, and supplies. It can increase their motivation because of stated goals, a set measurement procedure, incentives, and feedback of information.

(d) The program can result in greater awareness of efficiency, cost-consciousness, and time-consciousness by work center personnel.

(e) The program can extend and improve the PMS system. Since the output measure recommended in this instruction is PM's accomplished, there is greater emphasis on accomplishing scheduled PM's and on accomplishing unscheduled PM's when corrective maintenance is accomplished.

(f) The program can result in improved management decisions. The program can provide excellent and useful management information. This information in the form of productivity indices can be used along with quantitative, qualitative,

and subjective information to make management decisions on allocation of resources, scheduling of work, submitting requests for additional resources, and evaluating work center performance. The productivity indices, when used with other information, can be used to detect problem areas and unfavorable trends. The indices can be used as a basis for granting awards and rewards for superior performance. The indices can be used to support requests for additional resources when it can be shown that it would be impossible to achieve a given output with present resources.

Additionally, the program, if not properly implemented and administered, could produce unfavorable effects. Some of these are:

(a) The program could result in generating excessive paperwork.

(b) The program could result in poorer quality of work if work center personnel perceived that quantity not quality of work was desired. To avoid poorer quality of work, work center supervisors and above should continue to closely supervise the accomplishment of PMS. They should rigorously ensure that each maintenance action is properly accomplished with the proper tools, with the proper materials, by doing every step on the MRC (Maintenance Requirement Card), and by accomplishing the maintenance action on each piece of equipment on the EGL (Equipment Guide List) as applicable.

(c) The program could result in a misuse of the productivity data. The productivity indices alone are not useful

without other information such as subjective opinions. A statement such as "Work Center A is better than Work Center B because Work Center A has a higher productivity index than Work Center B" is a highly inaccurate, misleading, and false statement. The statement is a misuse of productivity data because it doesn't include information on possible reasons for differences such as differences in personnel, mission requirements, availability of resources, and other factors. Productivity indices must be used with other data and information to make valid statements, judgments, and decisions.

(d) The program could generate adverse or negative attitudes and emotions among work center personnel. Some individuals may feel that measurement of productivity "can't be done on a ship" and is therefore "unfair". Some individuals may feel frustrated if they feel that productivity goals are set unrealistically high. Additionally, a department head who says "working hours will be extended one hour per day until the productivity indices improve" will generate a great amount of ill feelings toward the program. To avoid generating adverse or negative attitudes and emotions work center supervisors and above should stress the positive benefits of the program and use the productivity indices in a positive manner.

(e) The program could provide information which is inaccurate. Relating the amount of PMS accomplished in a work center with the number of men assigned and with the amount of OPTAR spent may not be a useful measure in some departments

and work centers. This is true if a large portion of the personnel and OPTAR are used for activities not related to PMS accomplishment. To avoid this, an output measure should be selected which is representative of the activities of the work center. Another solution to this problem would be to submit feedback forms to include more work center activities in the PMS system. This would have the beneficial effect of extending the system.

4. Action. The objectives, guidelines, and suggestions of the Shipboard Productivity Improvement Program should be reviewed by all work center supervisors and above and implemented as considered appropriate.

XXXXXXXXXXXXXX

Distribution:

3M Manager

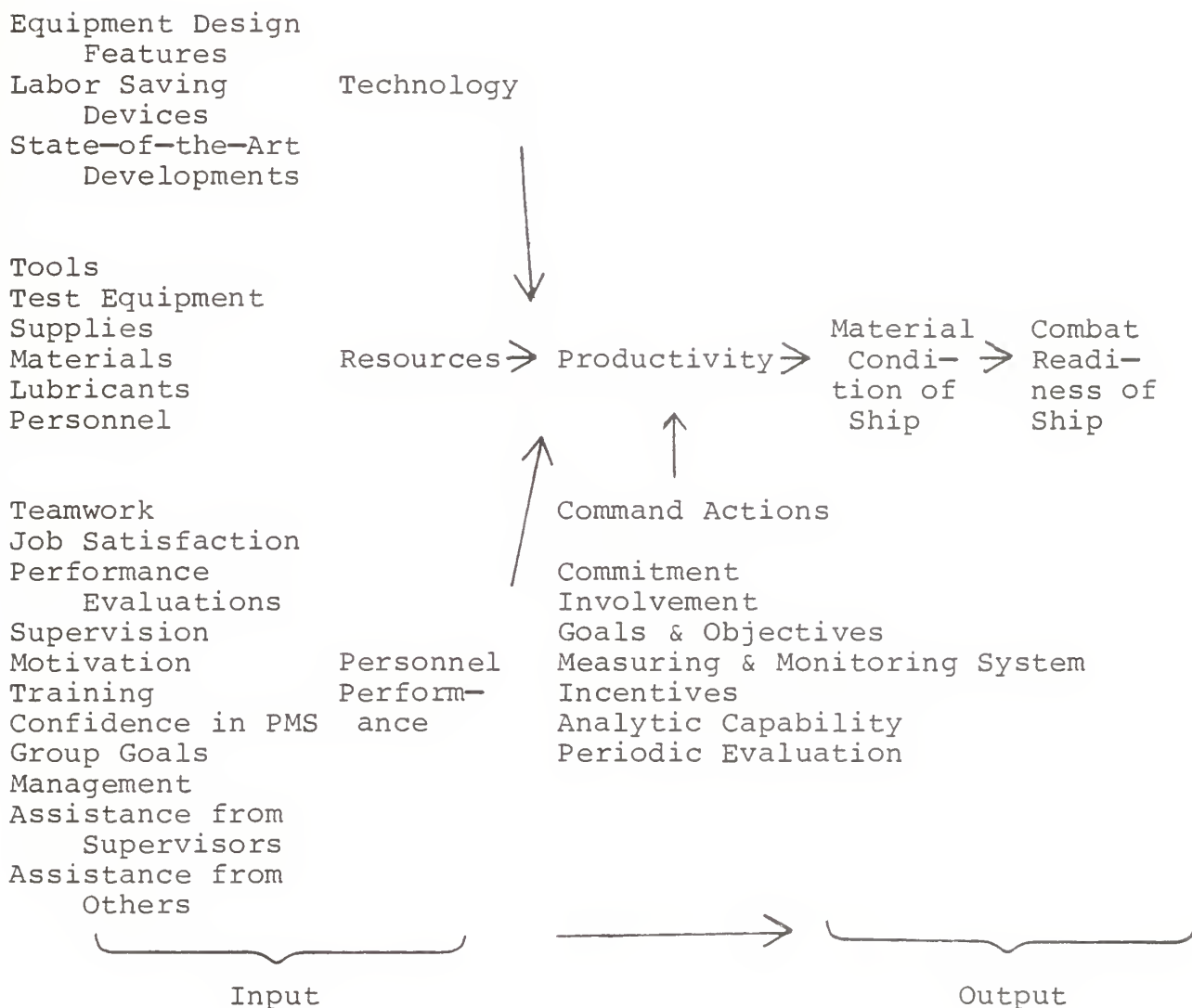
3M Coordinator

Department Heads

Departmental 3M Coordinators

Work Center Supervisors

FACTORS AFFECTING SHIPBOARD PRODUCTIVITY



Note: An effective way to provide an increased level of output without an increased level of input is through increased productivity. The focus of the effort should be toward the development of specific command actions involving any of the input factors which result in an improved level of productivity.

Enclosure (1)

PRODUCTIVITY DATA RECORD

1 WEEK	2 # PM's SCHEDULED	3 # PM's FULLY ACCOMPLISHED	4 # PM's PARTIALLY ACCOMPLISHED

INSTRUCTIONS: Fill this record out at the end of each week. In Column 1 insert the same dates as are shown on the PMS Weekly Schedule. Count the number of PM's scheduled during the week. Record the number in Column 2. Count the number of PM's fully accomplished (X's on the schedule). Record this number in Column 3. Count the number of PM's partially accomplished (circles with a P next to them). Record this number in Column 4. When corrective maintenance is accomplished ensure applicable PM's listed on the MIP (Maintenance Index Page) are also accomplished and recorded on the weekly schedule.

Enclosure (2)

DEPARTMENT _____
 PERIOD COVERING _____

DATE _____
 MONTH _____

PRODUCTIVITY DATA WORKSHEET

LINE #	DATA ITEM	WC	WC	WC	WC	DEPT TOTAL
1	# PM'S SCHEDULED					
2	# PM'S FULLY ACCOM					
3	# PM'S PART ACCOMP					
4	TOTAL (LINE 2 + $\frac{1}{2}$ LINE 3)					
5	AVE # PERSONNEL ASSIGNED					
6	AMT OF OPTAR CON- SUMED FOR MONTH					
7	% PMS ACCOM (LINE 4 ÷ LINE 1)					
8	PERSONNEL PRODUC- TIVITY INDEX -PPI (LINE 4 ÷ LINE 5)					
9	OPTAR PRODUCTIV- ITY INDEX - OPI (LINE 4 ÷ LINE 6)					

INSTRUCTIONS: Get data for lines #1, 2 & 3 from Productivity Data Record pages in Work Center Space Manuals. Compute line #4. Get data for line #5 from the Personnel Office. Get data for line #6 from the Supply Office. Compute lines #7,8, and 9.

Enclosure (3)

SAMPLE FORMAT
PRODUCTIVITY STATUS BOARD

PMS ACCOMPLISHMENT RATE

WORK CENTER	2 MONTHS AGO	LAST MONTH

DEPT AVERAGE	_____	_____

PERSONNEL PRODUCTIVITY INDEX

WORK CENTER	2 MONTHS AGO	LAST MONTH

DEPT AVERAGE	_____	_____

OPTAR PRODUCTIVITY INDEX

WORK CENTER	2 MONTHS AGO	LAST MONTH

DEPT AVERAGE	_____	_____

Enclosure (4)

SHIP EFFICIENCY QUESTIONNAIRE

A. Please fill in the information requested:

Ship _____ Work Center _____

Department _____

Are you the work center supervisor? ____ YES ____ NO

2-8

B. Read each question carefully. Then for each statement, place an X in the numbered box under the answer which most accurately describes your feelings.

1. To what extent do you have adequate tools to work efficiently?
2. To what extent do you have adequate supplies to work efficiently?
3. To what extent are you praised when you work efficiently?
4. To what extent are you chewed out when you work inefficiently?
5. To what extent do you get higher evaluations when you work efficiently?
6. To what extent do you get lower evaluations when you work inefficiently?
7. To what extent do your supervisors assist you to work efficiently?
8. To what extent do other men in your work center assist you to work efficiently?
9. To what extent do you enjoy your job?
10. To what extent are you motivated to work as efficiently as possible?
11. To what extent do you believe PMS is a good system?
12. To what extent do your shipboard training sessions help you learn to work more efficiently?
13. To what extent does your work center have goals to improve efficiency?
14. To what extent is there teamwork in your work center?
15. To what extent is your work adequately planned in advance in your work center?
16. To what extent do members of your work center encourage each other to give their best effort?

	To a very little extent	To a little extent	To some extent	To a great extent	To a very great extent	
1	2	3	4	5		9
1	2	3	4	5		10
1	2	3	4	5		11
1	2	3	4	5		12
1	2	3	4	5		13
1	2	3	4	5		14
1	2	3	4	5		15
1	2	3	4	5		16
1	2	3	4	5		17
1	2	3	4	5		18
1	2	3	4	5		19
1	2	3	4	5		20
1	2	3	4	5		21
1	2	3	4	5		22
1	2	3	4	5		23
1	2	3	4	5		24

Thank you for your cooperation - DO NOT SIGN YOUR NAME

SUMMARY OF 2212 RESPONSES TO
SHIP EFFICIENCY QUESTIONNAIRE

QUESTION #	QUESTION	MEAN	STAND. DEV.
1	Adequate tools?	2.63	1.05
2	Adequate supplies?	2.69	.95
3	Praise?	2.66	1.05
4	Reprimands?	3.30	1.12
5	High evaluations?	3.02	1.12
6	Low evaluations?	3.11	1.15
7	Supervisors assist?	3.22	1.12
8	Others assist?	3.28	1.06
9	Enjoy job?	3.07	1.32
10	Motivated?	3.01	1.20
11	PM's good?	3.40	1.26
12	Adequate training?	2.74	1.19
13	Efficiency goals?	2.92	1.14
14	Teamwork?	3.21	1.22
15	Adequate planning?	2.98	1.16
16	Encouragement?	2.80	1.20

N = 2212

Enclosure (6)

APPENDIX B: SHIP EFFICIENCY QUESTIONNAIRE

A. GENERAL COMMENTS

The Ship Efficiency Questionnaire shown in Appendix A was developed during the Spring 1976 at the U.S. Naval Postgraduate School, Monterey, California. It consists of 16 questions. It was modeled after the U.S. Navy Human Resources Management Survey. The questionnaire utilized the Likert Scale. The respondents marked each question according to the following key:

- 1 - To a very little extent
- 2 - To a little extent
- 3 - To some extent
- 4 - To a great extent
- 5 - To a very great extent

The Likert Scale was chosen due to the familiarity of U. S. Navy personnel with the scale and due to ordinal (ranking) characteristic of the scale. There were three objectives of the questionnaire:

- to identify factors or variables which strongly affect productivity,
- to identify possible problem areas on U. S. Navy ships with regard to the factors or variables affecting productivity,
- to identify differences between high and low productivity ships in terms of the factors or variables measured by the questionnaire.

Personnel from 22 of the 26 ships responded to the questionnaire. There were a total of 2212 respondents.

The analysis of the responses to the questionnaire was accomplished at the U. S. Naval Postgraduate School using

the SPSS (Statistical Package for Social Sciences) computer subroutines on an IBM 360/65 computer. The following statistical techniques were utilized:

- descriptive statistics to examine questionnaire responses,
- correlation analysis to determine relationships between questionnaire responses and productivity measures,
- regression analysis to determine if the questionnaire responses could be used to predict productivity measures,
- hypothesis testing using the t-test to determine if differences between the means per question between the high and low productivity ships were statistically significant,
- factor analysis to identify the general dimensions measured by the questionnaire.

B. DISCUSSION

A summary of the mean scores by question is provided in Appendix A. The per cent of respondents on each question selecting answers one through five on the Likert Scale is shown in Table B-I. In examining these tables, the following are observations:

- (1) The five highest means are for questions dealing with extent PMS is good, extent chewed out, extent others assist, extent supervisors assist, and extent of teamwork.
- (2) The five lowest means are for questions dealing with adequacy of tools, adequacy of supplies, extent of praise, adequacy of shipboard training, and extent of encouragement.

(3) The two lowest means were for the questions regarding the adequacy of tools and the adequacy of supplies. 39.3% and 36.7% of the respondents marked the lowest categories on the Likert Scale (1 or 2) in answering these two questions. In this author's opinion the relatively low mean scores and the high percentage of men selecting the lowest categories on the Likert Scale for the questions regarding adequacy of tools and the adequacy of supplies indicates that there are a large proportion of personnel on U. S. Navy ships who feel that their tools and supplies are inadequate to work efficiently. This is supported by the author's shipboard experience. Maintaining the proper amount and kind of tools and supplies are frequently major problems and are the source of complaints of enlisted personnel. Frequently enlisted personnel are heard saying, "we never have enough tools to work properly" and "we never have enough supplies (lubricants, rags, paint thinner, cleaning supplies, etc.) to work properly".

The questionnaire responses suggest both favorable and unfavorable attitudes and perceptions regarding factors affecting productivity. The following are this author's generalizations regarding the favorable perceptions of enlisted personnel on the 22 U. S. Navy ships who took the efficiency questionnaire:

- (1) They believe PMS is a good system.
- (2) They believe there is teamwork in their work centers.
- (3) They believe their supervisors assist them to work efficiently.

(4) They believe others in the work center assist them to work efficiently.

The following are this author's generalizations regarding the perceptions of enlisted personnel on the 22 U. S. Navy ships who took the questionnaire which suggest possible problem areas:

(1) They believe they have inadequate tools to work efficiently.

(2) They believe that have inadequate supplies to work efficiently.

(3) They believe their shipboard training sessions do not help them to learn to work more efficiently.

(4) They receive little praise when they work efficiently.

(5) They get "chewed out" when they don't work efficiently.

(6) They get little encouragement from other members in their work center to give their best effort.

To determine if there were any general dimensions measured by the questionnaire, a factor analysis of the questionnaire responses was conducted using the SPSS (Statistical Package for Social Sciences) computer subroutines. In the factor analysis the VARIMAX factor rotation was used. The correlation matrix, varimax factor matrix, and factor score coefficient matrix are shown in Tables B-II, B-III, and B-IV. The factor analysis indicated that there were five general dimensions measured by the questionnaire. These dimensions and the names provided by this author are shown below.

Factor	Dimension-Index Name
Factor 1	Management Index
Factor 2	Resources Index
Factor 3	Positive Leadership Index
Factor 4	Teamwork Index
Factor 5	Negative Leadership Index

The questions on the questionnaire associated with each dimension are shown in Table B-V. Index scores were computed for each dimension by adding the scores for each question in the dimension and then dividing by the number of questions in the dimension. Table B-VI is a summary of the mean index score for the 2212 respondents to the questionnaire.

To identify important factors or variables affecting productivity and to determine the relationships between the responses to the questionnaire and productivity measures, a statistical analysis of the data was accomplished. First, the Pearson correlation coefficient (r) was computed to determine the relationship between the mean scores per question per ship. Also the Pearson correlation coefficient (r) was computed to determine the relationship between the mean index score per ship and the mean planned maintenance actions per man per ship. Tables B-VII and B-VIII display the Pearson correlation coefficients. Second, the 26 U. S. Navy ships were divided into two groups according to their planned maintenance actions per man ratios. The two groups were designated the high productivity ships and the low productivity ships. Table B-IX shows the mean scores per question of personnel responding on the high and low productivity ships. Table B-X shows the mean scores per index of personnel responding on the high and low productivity ships.

In examination of Tables B-VII, B-VIII, B-IX and B-X, the following observations are made:

(1) The seven variables (questions) which had statistically significant differences in mean values between the high and low productivity ships using the t-test were: adequacy of tools, adequacy of supplies, extent supervisors assist, extent motivated, extent of teamwork, extent of planning, and extent of encouragement.

(2) Of these seven variables three had correlation coefficients above .50: adequacy of tools (.67), adequacy of supplies (.57), and extent of teamwork (.54). Additionally, the variable adequacy of planning had a correlation coefficient of .47.

(3) Three dimensions had indices which had statistically significant differences in mean values between the high and low productivity groups. These were the Resources Dimension, the Teamwork Dimension, and the Positive Leadership Dimension.

(4) Of these three dimensions one had a correlation coefficient above .50: Resources Dimension (.65).

The final aspect of the analysis of the questionnaire responses consisted of using multiple linear regression techniques with SPSS (Statistical Package for Social Sciences) computer subroutines to determine if mean scores per question per ship and mean index scores per ship could be used to predict specific productivity or performance measures. The following regression equations were computed (+ statistics in parentheses):

$$(1) \quad Y = -15.41 + 5.18X_1 + 4.16X_2 \quad \text{where}$$

$$(3.94) \quad (2.77)$$

Y = planned maintenance actions per man

X_1 = mean score on adequacy of tools question

X_2 = mean score on extent of teamwork question

Relevant statistics are:

$$r^2 = .61$$

$$F \text{ ratio (overall)} = 14.99$$

$$\text{Standard Error of Estimate} = 1.47$$

$$(2) \quad Y = -4.58 + 6.45X_1 + 4.54X_2 - 5.00X_3 \quad \text{where}$$

$$(4.28) \quad (2.58) \quad (2.25)$$

Y = planned maintenance actions per man

X_1 = mean score on Resources Index

X_2 = mean score on Teamwork Index

X_3 = mean score on Management Index

$$r^2 = .61$$

$$F \text{ ratio (overall)} = 9.20$$

$$\text{Standard Error of Estimate} = 1.524$$

$$(3) \quad Y = 1.96 + 23.55X_1 + 11.96X_2 + 13.05X_3 \quad \text{where}$$

$$(3.37) \quad (2.03) \quad (-1.90)$$

Y = PMS accomplishment rate

X_1 = mean score on teamwork question

X_2 = mean score on adequacy of tools question

X_3 = mean score on adequacy of training question

Relevant statistics are:

$$r^2 = .62$$

$$F \text{ ratio (overall)} = 9.59$$

$$\text{Standard Error of Estimate} = 6.521$$

$$(4) \quad Y = 17.58 + 32.91X_1 - 29.19X_2 + 15.69X_3 \quad \text{where}$$

$$(4.27) \quad (-3.00) \quad (2.38)$$

Y = PMS accomplishment rate

X_1 = mean score on Teamwork Index

X_2 = mean score on Management Index

X_3 = mean score on Resources Index

Relevant statistics are:

$$r^2 = .60$$

$$F \text{ ratio (overall)} = 8.92$$

$$\text{Standard Error of Estimate} = 6.521$$

Examination of these regression equations and the relevant statistics indicate the following to the author:

(1) The mean scores per question from the Ship Efficiency Questionnaire have some predictive capability to predict the level of productivity on a ship by predicting its mean planned maintenance actions per man ratio.

(2) The mean scores per question from the Ship Efficiency Questionnaire have some predictive capability to predict the level of PMS accomplishment on a ship by predicting its mean PMS accomplishment rate.

(3) The mean index scores per ship also have some predictive capability to predict the mean planned maintenance actions per man and the mean PMS accomplishment rate; however, the regression equations using the mean scores per question are considered superior.

C. CONCLUSIONS FROM THE EFFICIENCY QUESTIONNAIRE

The following are the conclusions of this author after analysis of the 2212 responses of enlisted personnel from 22 U. S. Navy Pacific Fleet ships:

- (1) The 2212 responses to the Efficiency Questionnaire shown in Appendix A indicate that the factors most highly correlated with productivity measure planned maintenance actions per man are adequacy of tools, adequacy of supplies, amount of teamwork, and adequacy of planning. In terms of each of these factors, ships with high productivity ratios (planned maintenance actions per man) had higher mean scores on these questions (adequacy of tools, adequacy of supplies, amount of teamwork, and adequacy of planning) than ships with low productivity ratios (planned maintenance actions per man). Department heads or commanding officers interested in enhancing productivity in their organizations should examine these factors and implement management actions designed to positively impact on these factors.
- (2) The 2212 responses to the Ship Efficiency Questionnaire indicate that the factors affecting productivity regarding adequacy of tools and adequacy of supplies may be problems on numerous ships. This is due to the fact that the two questions regarding these factors had low mean scores and that a large number of respondents marked one of the two lowest categories on the Likert Scale. Between 36% and 39% of the respondents marked the category on the Likert Scale that they felt they

had "to a very little extent" or "to a little extent" adequate tools and adequate supplies to work efficiently.

(3) The 2212 responses to the Ship Efficiency Questionnaire indicate that the factor amount of teamwork is highly correlated with the productivity measure planned maintenance actions per man. Additionally ships with high productivity ratios (planned maintenance actions per man) had a higher mean response score for the amount of teamwork than ships with low productivity ratios (planned maintenance actions per man). This suggests the importance of teamwork for high productivity. Additionally, this supports findings presented in Human Resource Management and Operational Readiness as Measured by Refresher Training on Navy Ships, by Dr. Sandra J. Mumford. That report stated that the Peer Teamwork Index from the Human Resources Management Survey was found to be strongly correlated ($r = .75$) with Full Refresher Training Unit Averages for 16 Navy ships (Mumford, 1976).

(4) The 2212 responses to the Ship Efficiency Questionnaire support the Joint Financial Management Improvement Program (JFMIP) model of a total performance measurement system shown in Figure 9 of this report. This model states and depicts that employee attitudes affect the effectiveness and efficiency of an organization. There were statistically significant differences between the high and low productivity ships on the mean scores on seven out of 16 questions at the .05 level of significance. These significant differences in the mean scores on the seven questions indicate that there

are substantial differences in the attitudes of the enlisted personnel on the high and low productivity ships.

(5) The Ship Efficiency Questionnaire shown in Appendix A is considered a valid instrument for measuring attitudes and perceptions of enlisted personnel on U. S. Navy ships regarding factors affecting productivity. The questionnaire was successfully pretested at the U. S. Naval Postgraduate School and successfully administered in the U. S. Pacific Fleet EMRM Project. By December 1976, approximately 5000 enlisted personnel will have taken the questionnaire.

(6) The Ship Efficiency Questionnaire can be used by work center supervisors, department heads, and commanding officers to measure attitudes and perceptions of their personnel. The questionnaire can be administered on a one-to-one interview basis or on a group basis. The interview method is recommended since specific problems or misunderstandings can be openly discussed. The questionnaire can be tailored to meet specific needs of the organization. For example, a department head may desire to ask questions regarding additional factors he feels may affect productivity in his department such as working hours, control over tools and supplies, degree of cleanliness in the departmental spaces, assignment of work, needs for specific tools, etc.

(7) Questions from the Ship Efficiency Questionnaire can be incorporated in the U. S. Navy Human Resources Management Survey which is administered throughout the U. S. Navy. A specific Productivity Index could be developed using questions

from the Ship Efficiency Questionnaire. The author recommends that the following two questions be added to the HRM Survey to form the Productivity Index:

(a) To what extent do you have adequate tools to work efficiently?

(b) To what extent do you have adequate supplies to work efficiently?

Table B-1. Summary of Proportion of Responses

	<u>Likert Scale</u>				
	1	2	3	4	5
Adequate Tools	18.7%	20.6%	41.3%	17.4%	2.1%
Adequate Supplies	12.8%	23.9%	46.0%	15.5%	1.8%
Extent of Praise	16.6%	22.2%	41.9%	15.7%	3.6%
Extent of Chewed Out	6.3%	13.1%	38.0%	27.1%	15.6%
Extent of High Evals	6.4%	16.3%	42.1%	29.1%	6.0%
Extent of Low Evals	6.1%	12.6%	43.5%	28.1%	9.6%
Extent Supervisors Assist	8.1%	13.3%	35.2%	32.1%	11.3%
Extent Others Assist	6.0%	11.5%	37.0%	36.0%	9.5%
Extent Enjoy Job	17.4%	11.4%	29.2%	27.4%	14.6%
Extent Motivated	11.6%	13.3%	37.5%	28.8%	8.8%
Extent PMS Good	7.2%	9.9%	30.8%	30.6%	21.4%
Extent Training Effective	14.3%	21.0%	37.1%	22.2%	5.4%
Extent Efficiency Goals	9.1%	19.1%	39.7%	25.9%	6.3%
Extent of Teamwork	8.2%	12.1%	34.3%	32.0%	13.3%
Extent of Planning	10.4%	15.6%	37.8%	29.6%	6.5%
Extent of Encouragement	14.3%	18.4%	39.0%	21.4%	6.8%

N = 2212

Table B-II. Ship Efficiency Questionnaire Correlation Coefficients

PRODUCTIVITY MEASUREMENT AND ENHANCEMENT ON US NAVY SHIPS
FACTOR ANALYSIS OF RESP TO SHIP EFFICIENCY QUESTIONNAIRE
FILE ENLISTED (CREATION DATE = 09/07/76) PERSONNEL IN PAY GRADES E-1 TO E-9 ON 22 SHIPS
09/07/76

CORRELATION COEFFICIENTS..

[illegible][illegible]

DETERMINANT OF CORRELATION MATRIX = 0.0071098(0.71098283D-02)

1-VARIABLE LIST

VARIABLES..	LABELS..	VARIABLE	MEAN	STANDARD DEV	CASE#
ADTOOL	ADEQUACY OF TOOLS IN WC	ADTOOL	2.6279	1.0490	1
ADSUPP	ADEQUACY OF SUPPLIES IN WC	ADSUPP	2.6903	0.9494	2
APRAISE	AMOUNT OF PRAISE IN WC	APRAISE	2.6618	1.0537	3
CHEVAL	RECEIPT OF REPRIMAND IN WC	CHEVAL	3.2979	1.1825	4
HIEVAL	RECEIPT OF HIGHER EVALS IN WC	HIEVAL	3.0154	1.1045	5
LOEVAL	RECEIPT OF LOWER EVALS IN WC	LOEVAL	3.1080	1.4944	6
SUPPASS	RECEIPT OF SUPERIOR ASSIST IN WC	SUPPASS	3.2242	1.1627	7
OTHASS	OTHER ASSIST IN WC	OTHASS	3.2762	1.0558	8
DEGREEE	OTHER ENJOYED THEIR JOB IN WC	ENJOY	3.0683	1.2328	9
DEGREEE	MEN MOTIVATED IN WC	MOTIV	3.0127	1.0441	10
DEGREEE	BELIEVE PMTS IS A GOOD SYSTEM	PMGOOD	3.3974	1.0399	11
EXTENT	TRAINING EFFECTIVE IN WC	TRAIN	3.7373	1.6899	12
EXTENT	TRAINING EFFECY GOALS IN WC	GOALS	2.9168	1.4468	13
EXTENT	OF TEAMWORK IN WC	TEAMWK	2.2051	1.158	14
EXTENT	OF PLANNING IN WC	PLAN	2.9757	1.6258	15
EXTENT	OTHERS ENCOURAGE IN WC	ENCCOUR	2.7957	1.1958	16

Table B-III. Ship Efficiency Questionnaire Factor Score Coefficients

PRODUCTIVITY MEASUREMENT AND ENHANCEMENT ON US NAVY SHIPS
 FACTOR ANALYSIS OF RESP TO SHIP EFFICIENCY QUESTIONNAIRE
 FILE ENLISTED (CREATION DATE = 09/07/76) PERSONNEL IN PAY GRADES E-1 TO E-9 ON 22 SHIPS 09/07/76

FACTOR SCORE COEFFICIENTS					
	MANAGEMENT DIMENSION	RESOURCES DIMENSION	POSITIVE LEADERSHIP DIMENSION	TEAMWORK DIMENSION	NEGATIVE LEADERSHIP DIMENSION
	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
ADTOOL	-0.03721	0.48995	-0.03335	-0.01228	-0.00355
ADSUPP	-0.04376	0.59371	-0.02102	-0.01652	0.01653
PRAISE	-0.05474	-0.03233	0.39635	-0.03666	-0.08126
CHEWED	0.01761	0.00927	-0.08578	0.02597	0.09477
HIEVAL	-0.03589	-0.00453	0.30077	-0.05413	-0.00160
LOEVAL	-0.03264	-0.02196	0.11218	-0.04079	0.85978
SUPASS	-0.08328	-0.02283	0.22838	0.11942	-0.04341
OTHASS	-0.16644	0.00234	0.09885	0.36907	-0.00259
ENJOY	0.04001	0.00362	0.13343	-0.02293	-0.04641
MOTIV	0.24960	-0.02555	0.08761	-0.12891	-0.05769
FMGOOD	0.17896	0.00097	-0.06264	-0.10684	0.01484
TRAIN	0.21803	-0.02649	0.04101	-0.13289	0.00055
GOALS	0.24507	-0.05314	-0.03278	-0.03386	0.03750
TEAMWK	0.10243	-0.03559	-0.20311	0.49348	0.04251
PLAN	0.19076	0.00430	-0.02590	-0.01054	-0.00373
ENCOUR	0.11374	-0.02912	-0.05497	0.21484	0.01346

Table B-IV. Ship Efficiency Questionnaire VARIMAX Factor and Transformation Matrix

PRODUCTIVITY MEASUREMENT AND ENHANCEMENT ON US NAVY SHIPS
 FACTOR ANALYSIS OF RESP TO SHIP EFFICIENCY QUESTIONNAIRE
 FILE ENLISTED (CREATION DATE = 09/07/76) PERSONNEL IN PAY GRADES E-1 TO E-9 ON 22 SHIPS 09/07/76

VARIMAX ROTATED FACTOR MATRIX					
	MANAGEMENT DIMENSION	RESOURCES DIMENSION	POSITIVE LEADERSHIP DIMENSION	TEAMWORK DIMENSION	NEGATIVE LEADERSHIP DIMENSION
	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
ADTOOL	0.15822	0.77186	0.09814	0.07103	-0.00345
ADSUPP	0.14771	0.77719	0.11220	0.06326	0.02840
PRAISE	0.23004	0.07240	0.62295	0.09785	-0.10301
CHEWED	0.00793	0.01050	-0.09287	0.02907	0.45851
HIEVAL	0.18188	0.10687	0.56667	0.03430	0.24666
LOEVAL	0.00553	-0.00066	0.19062	-0.02315	0.89880
SUPASS	0.15418	0.05141	0.48336	0.29090	-0.03173
OTHASS	0.09230	0.07221	0.21102	0.62945	-0.01242
ENJOY	0.36716	0.13476	0.37253	0.12253	-0.08970
MOTIV	0.65511	0.11200	0.30099	0.12608	-0.06484
FMGOOD	0.54374	0.10190	0.05098	0.01482	0.11799
TRAIN	0.61877	0.09017	0.25555	0.05308	0.03848
GOALS	0.67266	0.05189	0.17853	0.23762	0.05434
TEAMWK	0.51769	0.06332	0.04182	0.64544	0.04400
PLAN	0.62705	0.15198	0.17363	0.26271	0.01257
ENCOUR	0.55513	0.07591	0.13819	0.49785	0.00894

TRANSFORMATION MATRIX

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
FACTOR 1	0.75021	0.27938	0.43066	0.41477	0.04037
FACTOR 2	-0.16820	0.17517	0.24604	-0.15924	0.92473
FACTOR 3	-0.18755	0.91933	-0.01317	-0.24234	-0.24649
FACTOR 4	0.19317	0.19937	-0.84262	0.36357	0.28417
FACTOR 5	-0.58001	0.07968	0.20932	0.78211	-0.04161

Table B-V: Dimensions of the Efficiency Questionnaire

Management Dimension

- Extent of motivation
- Extent PMS is good
- Adequacy of shipboard training
- Extent of efficiency goals
- Adequacy of planning

Resources Dimension

- Adequacy of tools
- Adequacy of supplies

Positive Leadership Dimension

- Extent of praise
- Extent of high evaluations
- Extent supervisors assist
- Extent enjoy job

Teamwork Dimension

- Extent others assist
- Extent of teamwork
- Extent of encouragement

Negative Leadership Dimension

- Extent of being "chewed out"
- Extent of low evaluations

Table B-VI. Summary of Mean Index Scores by Ship

<u>Index</u>	<u>Mean</u>	<u>Stand.Dev.</u>
Management Index	3.01	.89
Resources Index	2.66	.91
Positive Leadership Index	2.99	.81
Teamwork Index	3.09	.95
Negative Leadership Index	3.20	.95

N = 22

Table B-VII. Pearson Correlation Coefficients between Mean Planned Maintenance Actions per Man and Mean Questionnaire Scores by Ship

<u>Question</u>	<u>Pearson Correlation Coefficient - r</u>	<u>p</u>
Adequate Tools	.67*	(.001)
Adequate Supplies	.57*	(.003)
Praise	-.15	(.245)
Chewed Out	.22	(.157)
High Evaluations	.01	(.488)
Low Evaluations	.12	(.300)
Supervisors Assist	.11	(.317)
Others Assist	.29	(.096)
Enjoy Job	.33	(.068)
Motivated	.20	(.185)
PMS Good	-.27	(.109)
Adequate Training	-.19	(.198)
Efficiency Goals	-.15	(.253)
Teamwork	.54*	(.005)
Adequate Planning	.47*	(.014)
Encouragement	.27	(.115)

N = 22

Note: * indicates significant at .05 level of significance.
Level of significance (P) indicated in parentheses.

Table B-VIII. Pearson Correlation Coefficients between Mean Planned Maintenance Actions per Man and Mean Index Scores by Ship

<u>Index</u>	<u>Pearson Correlation Coefficient - r</u>	<u>p</u>
Management Index	.00	(.495)
Resources Index*	.65	(.001)
Positive Leadership Index	.10	(.333)
Teamwork Index*	.41	(.030)
Negative Leadership Index	.07	(.378)

Note: N = 22 * indicates significant at .05 level of significance. Level of significance indicated in parentheses.

Table B-IX. Comparison of High and Low Productivity Ships in Terms of Mean Responses per Question

<u>Question</u>	<u>High Productivity Ships</u>	<u>Low Productivity Ships</u>	<u>t- value</u>	<u>p</u>
Adequate tools*	2.75	2.53	4.97	(.001)
Adequate supplies*	2.78	2.62	3.96	(.001)
Amount of praise	2.70	2.63	1.62	(.105)
Chewed out	3.32	3.28	.79	(.432)
High evaluations	3.05	2.98	1.42	(.157)
Low evaluations	3.14	3.08	1.35	(.178)
Supervisors assist*	3.28	3.17	2.20	(.028)
Others assist	3.31	3.24	1.73	(.085)
Enjoy job	3.12	3.03	1.60	(.110)
Motivated*	3.07	2.96	2.15	(.031)
PMS good	3.43	3.37	1.11	(.266)
Training effective	2.70	2.78	-1.47	(.143)
Efficiency goals	2.93	2.91	.43	(.669)
Teamwork*	3.30	3.13	3.35	(.001)
Planning*	3.04	2.92	2.49	(.013)
Encouragement*	2.90	2.71	3.67	(.001)

*N = 2212. * indicates significant differences between means at .05 level of significance. Level of significance of t-values indicated in parentheses.

Table B-X. Comparison of High and Low Productivity Ships in Terms of Mean Response Scores on Indices

<u>Index</u>	<u>High Productivity Ships</u>	<u>Low Productivity Ships</u>	<u>t- value</u>	<u>p</u>
Management Index	3.04	2.99	1.27	(.205)
Resources Index*	2.76	2.57	4.96	(.001)
Positive Leader- ship Index*	3.04	2.95	2.44	(.015)
Teamwork Index*	3.17	3.03	3.62	(.001)
Negative Leader- ship Index	3.23	3.18	1.28	(.200)

Note: N = 2212 * indicates significant differences between means at .05 level of significance using t-test. Level of significance of t values indicated in parentheses.

APPENDIX C: SHIP PRODUCTIVITY REPORT

To develop a usable productivity report to feed back productivity information to U. S. Navy ships, numerous productivity measurement and enhancement programs and sample productivity reports were studied and analyzed. Programs and reports from the following organizations were reviewed:

- Department of Defense Productivity Program,
- Department of the Navy Productivity Program,
- Defense Supply Agency's Performance Evaluation Reporting System
- Naval Supply Systems Command Activity Management Report
- National-American Wholesale Grocers' Association Warehousing Productivity Measurement Program (NAWGA)

The NAWGA Warehousing Productivity Measurement Program Overall Performance Report is shown in Figure C-1.¹ This author considers it one of the superior productivity reports reviewed in this research. NAWGA's program and report have many characteristics which are applicable to U. S. Navy ships. The productivity measure used in NAWGA's program is TPMH (Tons of merchandise moved per man hour). NAWGA's report provides the functional breakdown of warehousing functions: receiving, shipping, repacking, indirect labor (supervision, etc.), and support. Productivity ratios (called operating levels) are listed for each of these functions and subfunctions for the current month, for the past year (average), and

¹This report was provided by the National Center for Productivity and Quality of Working Life. Permission to reproduce the report was received from the National Center.

Figure C-1. NAWGA Overall Performance Report.

NAWGA'S WCCS REPORT FOR

GROCERY DEPT (RETAIL ONLY)
OVERALL PERFORMANCECODE NUMBER 041-2
APR 5-76 PAGE 1

		AVERAGES 11 LARGE OPERATIONS		AVERAGES 7 LARGE OPERATIONS		AVERAGES 8 LARGE OPERATIONS		AVERAGES 6 LARGE OPERATIONS		AVERAGES 6 LARGE OPERATIONS	
		* AVERAGE TOTAL AREA = 252,382 SQ FT		WITH UNDER 46 TONS SHIPPED / 1000 SQ FT		WITH UNDER 2 TONS STORED / 1000 CU FT		WITH OVER 4,801 INVENTORY ITEMS		WITH FOUR WEEK-SALES UNDER 12 1,000 TONS	
		THIS TIME LAST YEAR OPERATING LEVEL		THIS TIME LAST YEAR OPERATING LEVEL		THIS TIME LAST YEAR OPERATING LEVEL		THIS TIME LAST YEAR OPERATING LEVEL		THIS TIME LAST YEAR OPERATING LEVEL	
		PAST YEAR AVERAGE OPERATING LEVEL		PAST YEAR AVERAGE OPERATING LEVEL		PAST YEAR AVERAGE OPERATING LEVEL		PAST YEAR AVERAGE OPERATING LEVEL		PAST YEAR AVERAGE OPERATING LEVEL	
		FEB 28-76		FEB 28-76		FEB 28-76		FEB 28-76		FEB 28-76	
		1.31		1.27		3.15+		1.19		1.77	
		1.99		1.97		1.02+		1.95		1.92	
		2.35		2.40		2.08-		2.25		2.60	
		8.40		8.31		1.08+		8.73		9.88	
		2.00		1.44		38.89+		0.96		2.27	
		223.84		163.21		37.15+		148.81		45.08	
		0.53		5.55		90.45-		9.84		6.46	
		3.22		3.26		1.23-		3.10		3.63	
		1.73		1.67		3.59+		1.71		1.51	
		2.23		2.14		4.21+		2.22		1.99	
		7.69		7.61		1.05+		7.46		6.32	
		0.24		0.25		4.00-		0.24		0.79	
		8.92		7.83		13.92+		6.36		5.49	
		19.10		17.06		11.96+		14.41		21.93	
		777.00		108.61		615.40+		45.56		47.53	
		24.20		24.27		0.29-		22.40		29.46	
		0.00		459.33		100.00-		0.00		32.28	
		101.19		102.75		1.52-		101.68		93.15	
		36.02		34.19		5.35+		29.91		43.93	
		13.67		13.98		2.22-		14.04		7.67	
		109.88		112.69		2.49-		87.42		21.93	
		26.43		27.62		4.31-		28.29		47.53	
		38.17		37.84		0.87+		40.93		29.46	
		*****		*****		*****		*****		*****	
		10,818		10,378		4.24+		9,551		12,651	
		81,562		79,491		2.61+		75,910		99,724	
		1.00		0.90		11.11+		1.00		1.50	
		3.75		3.79		1.06-		3.99		3.91	
		0.11		0.11		0.00+		0.12		0.11	
		5.50		6.10		9.84-		1.70		4.70	
		5,548		5,272		5.24+		4,769		8,684	
		25.36		25.61		0.98-		26.06		18.57	
		1,184		1,126		5.15+		1,132		1,703	
		652		675		3.41-		632		564	
		114						173		217	
		5,517		5,272		5.24+		4,769		8,684	
		18.95		18.57		0.98-		18.63		18.95	
		1,243		1,126		5.15+		1,132		1,703	
		476		675		3.41-		632		523	
		168						173		217	
		229.50		208.70		4.24+		45.76		250.00	
		35.01		49.73		5.23+		45.76		50.60	
		24.04		25.26		0.00+		22.85		34.74	
		4,743		5,152		0.00+		5,152		4,684	

for the current month one year ago. Additionally, for comparison purposes, productivity ratios are listed for similar organizations, by the size of their area, by the number of tons shipped, and by their sales volume.

Mr. Gerald E. Peck, Executive Vice President of the National-American Wholesale Grocers' Association presented NAWGA's Warehousing Productivity Measurement Program at the "Productivity Improvement through Measurement Seminar" held in Washington, D. C. on 23 June 1976. The seminar was sponsored by the National Center for Productivity and Quality of Working Life. Mr. Peck stated,

"NAWGA provides forms, definitions and instructions to members to aid in the collection of data required for a performance analysis. Four week accounting periods are used for convenience and consistency. When received, the data is audited then keypunched into a computer. The computer program produces a printout with productivity ratios for all key warehousing functions. The printout also compares each current ratio with the average of the last 13 periods, with the same period in the previous year and with other operators. In every case, comparisons with other operators are made only against those of similar sales, physical size, items carried and other productivity influencing conditions.

"The essence of the program is its isolation of strengths and weaknesses in basic functions, more than in overall terms. It is designed as a tool for line management. A summary report is run separately for the chief executive."

In developing a productivity report suitable for use for U. S. Navy ships, sample reports were first developed and evaluated using the data being collected for the 26 ships in the EMRM Project. The following were the objectives for these reports:

- (1) The reports were to be automated (computer-based).

- (2) The reports were to be easy-to-read.
- (3) The reports were to stand by themselves and not require reference to instructions or letters to be understood.
- (4) The reports were to permit comparison of overall ship productivity of a specific ship with the productivity of similar ships.
- (5) The reports were to permit comparison of the productivity of a specific work center with the productivity of the same work center on similar ships.
- (6) The reports were to show changes in productivity if they occurred over time for the detection of trends.
- (7) The reports were to be designed as management reports to be sent directly to the commanding officers of the reporting ships with no copies provided to higher authority.

Figure C-2 is the format of the productivity report developed for use with the data collected for the 26 U. S. Navy ships. This format is the third format used with the data. The first format was for a manually produced report. It consisted of a listing of productivity and average cost ratios by ship. Ratios for all 26 ships were listed but only the ship to whom the report was sent was identified. This was to maintain confidentiality and to provide commanding officers with information as to where their ship ranked overall in terms of the ratios. The second format was an automated report. It consisted of listing productivity ratios by work center for each reporting ship. Both of these reports were sent to 13 of the 26 ships for which the data was being

Figure C-2. PACFLT EMRM Program Monthly Performance Summary.

PACFLT EMRM PROGRAM MONTHLY PERFORMANCE SUMMARY										
1	2	3	4	5	6	7	8	9	10	
Unit	%FMS ACCOM	% CHG FROM ONE MONTH AGO	FM'S PER MAN-HOUR	% CHG FROM ONE MONTH AGO	CM'S PER MAN HOUR	% CIG FROM ONE MONTH AGO	% FM'S ACCOM OTHER SHIPS	FM'S PER MAN-HOUR OTHER SHIPS	CM'S IER MAN-HOUR OTHER SHIPS	
All ships										
All com-batants										
All work centers this ship										
Work centers										
DA 01										
EA 03										
FE 02										
DD 04										
SS 02										
WH 01										
ER 04										
etc										

Notes: Information on this sheet summarizes data provided by work centers from all ships participating in the PACFLT EMRM Project as reported on PACFLT EMRM PROGRAM SHIP'S FORCE WEEKLY MAINTENANCE SUMMARY (REV 10/10/75). Column 2 is the per cent of FMS MR's completed with 1/2 credit for IMS MR's partially completed compared with FMS MR's scheduled. Column 4 is IMS MR's completed with 1/2 credit for FMS MR's partially completed divided by the number of man-hours expended on FMS. Column 6 is CM (Corrective Maintenance) actions completed divided by the number of man-hours expended on CM actions. Columns 3,5, and 7 show the percentage change from last month. Column 8 shows the average % FM's accomplished by work centers of the same designation (dept and division) from ships of the same type for the current month. Column 9 shows the average FM's per man-hour by work centers of the same designation (dept and division) from ships of the same type. Column 10 shows the average CM's per man-hour by work centers of the same designation (dept and division) from ships of the same type. THIS SUMMARY IS NOT PROVIDED TO HIGHER AUTHORITY.

collected. The report shown in Figure C-2 was developed during the final months of the EMRM Project. This report was programmed in the COBOL (Common Business Oriented Language) computer language.

The Ship Productivity Report shown in Figure C-3 is the format of a productivity report the author considers feasible for general use for U. S. Navy ships. It was designed after taking into account the findings of this research and the experience gained in designing and using productivity reports with the data being collected on 26 ships participating in the EMRM Project. The Ship Productivity Report shown in Figure C-3 would require the following information be submitted monthly by work center for each reporting ship:

- number of MR's (maintenance requirements) fully accomplished during the month by each work center,
- number of MR's partially accomplished during the month by each work center,
- number of enlisted men assigned to each work center,
- amount of OPTAR consumed for each work center during the month.

The amount of OPTAR should be the total amount of OPTAR consumed to include equipage, repair parts, and consumables.

The following ratios are listed on the Ship Productivity Report shown in Figure C-3:

- PMS accomplishment rate,
- per cent change in PMS accomplishment rate from one month ago,

Figure C-3. Ship Productivity Report.

SHIP PRODUCTIVITY REPORT

1	2	3	4	5	6	7	8	9	10
UNIT	PMS ACCOM RATE	% CHG FROM ONE MONTH AGO	MAINTEN ACTIONS PER MAN	% CHG FROM ONE MONTH AGO	MAINTEN ACTIONS OPTAR \$	% CHG FROM ONE MONTH AGO	INS ACCOM RATE OTHER SHIPS	MAINTEN ACTIONS PER MAN OTHER SHIPS	MAINTEN ACTIONS OPTAR \$ OTHER SHIPS

All ships

All com-
batants

All work
centers
this ship

Work centers

DA 01
EA 03
EE 02
DD 04
etc

Note: Information on this report summarizes data provided by reporting ships. Column 2 is the IMS accomplishment rate which is the per cent of MR's fully accomplished with 1/2 credit for MR's partially accomplished compared with MR's scheduled. Column 4 is the maintenance actions per man ratio which is the number of MR's fully accomplished with 1/2 credit for partials divided by the average number of man assigned. Column 6 is the maintenance actions per OPTAR \$ consumed which is the number of MR's fully accomplished with 1/2 credit for partials divided by the amount of OPTAR consumed. Columns 3, 5, and 7 show the percentage change from the previous month. Columns 8, 9, & 10 show the average PMS accomplishment rate, the average maintenance actions per man ratio, and the average maintenance actions per OPTAR \$ consumed ratio for work centers of the same designation (dept and division) for ships of the same type. THIS REPORT IS NOT PROVIDED TO HIGHER AUTHORITY.

- planned maintenance actions per man,
- per cent change in maintenance actions per man from one month ago,
- planned maintenance actions per OPTAR dollar consumed,
- per cent change in planned maintenance actions per OPTAR dollar consumed from one month ago,
- PMS accomplishment rate for similar ships and for the same work center on similar ships,
- planned maintenance actions per man for similar ships and for the same work center on similar ships,
- planned maintenance actions per OPTAR dollar consumed for similar ships and for the same work center on similar ships.

The Ship Productivity Report shown in Figure C-3 uses the output measure planned maintenance actions accomplished. Planned maintenance actions accomplished is the sum of all MR's fully accomplished and 1/2 of all the MR's partially accomplished. The input measures used in the report are the average number of men assigned and the amount of OPTAR dollars consumed. The average number of men assigned is the sum of the number of men assigned on the first day of the month and the last day of the month divided by 2. The amount of OPTAR dollars consumed is the total amount of OPTAR consumed during the month. It is the author's opinion that all OPTAR costs are related to the amount of planned maintenance accomplished and therefore should be included in the input measure. Using total OPTAR costs results in a more general and more

comprehensive productivity measure than would result by using only OPTAR dollars consumed for repair parts.

It is emphasized that the productivity reports shown in Figures C-2 and C-3 are intended to be used as management reports as individual commanding officers desire. Strict confidentiality is considered important to avoid the manipulation of the input data. The confidentiality would consist of the requirement that the report be sent only to the commanding officers of the reporting ships with no copies to seniors or to other officers. The confidentiality for this report would be exactly like the confidentiality of the U. S. Navy Human Resources Management Survey results.

There are obvious advantages and disadvantages in producing productivity reports for U. S. Navy ships. Some of the advantages are:

- (1) They provide useful management information to help identify weak and strong areas, unfavorable and favorable trends, etc.
- (2) They provide an increased awareness of productivity, output, and input.
- (3) They provide a means to help evaluate the effects of management actions to improve productivity.
- (4) They could motivate officers and enlisted personnel to improve productivity.

Some of the disadvantages are:

- (1) They require the collection of data.

(2) They could be misused such as basing decisions on a productivity report without using other relevant information.

(3) They could be inaccurate and misleading if the data input was inaccurate or falsified.

(4) They could be costly in terms of computer time.

As a result of designing and using productivity reports in this research, the author presents the following opinions:

(1) Automated productivity reports for U. S. Navy ships using maintenance, personnel, and OPTAR cost data is feasible and within the "state of the art" in terms of MIS (management information systems), computer software, and computer hardware.

(2) Automated productivity reports for U. S. Navy ships would require the collection of maintenance, personnel, and OPTAR cost data that is not normally collected on all U. S. Navy ships.

(3) Non-automated (manually produced) productivity reports for U. S. Navy ships can be produced for a single ship as outlined in Appendix A (Shipboard Productivity Improvement Program).

(4) Automated productivity reports are potentially very useful management reports which are similar to reports used by commercial companies in the private sector.

APPENDIX D. SAMPLE PRODUCTIVITY PUBLICATIONS

EXCERPTS FROM
NATIONAL CENTER FOR PRODUCTIVITY
AND
QUALITY OF WORKING LIFE
CURRENT PUBLICATIONS

April 1976

National Center for Productivity
and
Quality of Working Life
2000 M Street, N.W.
Washington, D.C.

A NATIONAL POLICY FOR PRODUCTIVITY IMPROVEMENT
1975 36 pp.

A statement by the National Commission on Productivity and Work Quality on national productivity policy. Designed as a basis for future efforts of the Center and its staff.

FOURTH ANNUAL REPORT OF THE NATIONAL COMMISSION ON
PRODUCTIVITY AND WORK QUALITY 1975 56 pp.

An account of the Commission's activities during 1974. Also offers an analysis of cyclical variations in productivity growth as far back as 1889; isolates factors which caused downturns; and suggests positive government policies that might discourage decline and extend periods of rapid growth.

THIRD ANNUAL REPORT OF THE NATIONAL COMMISSION ON
PRODUCTIVITY 1974 66 pp.

Annual report to the President and Congress of the Commission's activities in 1973. Includes tables showing the year-to-year statistical changes in a number of areas directly related to productivity.

PRODUCTIVITY CENTERS AROUND THE WORLD 1975 36 pp.

Describes the objectives, functions, and operations of major productivity centers around the world. Suggests some reasons for their continued growth and influence. Centers described in case studies include members of the European Association of National Productivity Centers (Belgium, Bulgaria, Czechoslovakia, Denmark, France, West Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxemburg, the Netherlands, Norway, Portugal, Spain, Turkey, and Yugoslavia) and Australia, Israel, Japan, New Zealand, and South Africa.

THE ROLE OF PRODUCTIVITY IN CONTROLLING INFLATION
1974 28 pp.

Study paper. Major causes of current inflation. Includes a detailed sector-by-sector analysis of the favorable impact increased productivity can have on rising prices and the general health of our economy.

THE STATUS OF PRODUCTIVITY MEASUREMENT IN STATE
GOVERNMENT: AN INITIAL EXAMINATION 1975 238pp.

The first survey of State budget officers' perception as to the current use of productivity and effectiveness measures. Seeks to identify the adequacy of productivity information available regularly to public officials.

IMPROVING MUNICIPAL PRODUCTIVITY: WORK MEASUREMENT
FOR BETTER MANAGEMENT 1975 36 pp.

Describes uses of and benefits derived from the application of work measurement techniques to municipal functions. Illustrates how these techniques have been applied to enhance local government productivity. Intended to aid managers and staff analysts in understanding these concepts and their application.

SO, MR. MAYOR, YOU WANT TO IMPROVE PRODUCTIVITY
1974 32 pp.

Guidelines for the chief executive of any government organization for implementing a productivity improvement program. Covers union participation and public understanding. Describes an approach to obtaining and organizing the analytical resources required to achieve the full potential from a productivity improvement program.

THE WINGSPREAD CONFERENCE: PRODUCTIVITY IN STATE AND
LOCAL GOVERNMENT 1973 28 pp.

The major barriers to improving productivity in State and local government as viewed by 50 key governors, mayors, city managers, and county executives.

IMPROVING POLICE PRODUCTIVITY: A BRIEF FOR ELECTED
OFFICIALS 1973 16 pp.

Subtitled More for Your Law Enforcement Dollar. Information to help elected officials assess the productivity of police services. Also identifies improvement techniques tried in selected jurisdictions.

CONFERENCE ON AN AGENDA FOR ECONOMIC RESEARCH ON
PRODUCTIVITY 1973 68 pp.

Scholarly appraisals of what can be done through economic research to broaden knowledge of productivity measurement and growth and the impact of cyclical variation and productivity change. A critical review of the state of knowledge, major gaps, and research priorities in various fields.

PUBLIC SECTOR

LABOR MANAGEMENT COMMITTEES IN THE PUBLIC SECTOR:
EXPERIENCES OF EIGHT COMMITTEES 1976 76 pp.

Based on interviews with practitioners. Describes the experiences of eight labor-management committees which have been operating in various local government and Federal agencies. Intended as a guide to initiating joint committees to improve employee morale and productivity.

A JURISDICTIONAL GUIDE TO PRODUCTIVITY IMPROVEMENT
PROJECTS, plus Quarterly Updates 1975 115 pp.

Subtitled A Handbook for Public Officials. Prepared by International City Management Association. Demonstrates the many and various approaches and techniques which have been utilized across the country to improve local government productivity. Organized by specific functions, such as energy conservation, general administration, inspections, parks and recreation, public safety, public works, etc.

EMPLOYEE INCENTIVES TO IMPROVE STATE AND LOCAL
GOVERNMENT PRODUCTIVITY 1975 182 pp.

Describes the different employee incentive programs in use in State and local governments throughout the U.S. Reviews a sampling of these programs and shows results obtained by the various governments. Offers guidelines on the implementation of incentive programs.

OPPORTUNITIES FOR IMPROVING PRODUCTIVITY IN POLICE
SERVICES 1973 76 pp.

Report of the Advisory Group on Productivity in Law Enforcement. Identifies issues relating to productivity within patrol, crime prevention, and human resources; explores the potential for developing more precise measures; and provides examples of improvement techniques.

IMPROVING PRODUCTIVITY IN SOLID WASTE COLLECTION: A
BRIEF FOR ELECTED OFFICIALS 1973 12 pp.

Information to help elected officials assess the productivity of residential solid waste collection systems. Also identifies improvement techniques tried in selected jurisdictions.

OPPORTUNITIES FOR IMPROVING PRODUCTIVITY IN SOLID WASTE
COLLECTION 1973 48 pp.

Report of the Solid Waste Management Advisory Group. Identifies common problems affecting residential solid waste collection systems, and offers suggestions for improving and measuring the productivity of this municipal and county function.

IMPROVING PRODUCTIVITY AND PRODUCTIVITY MEASUREMENT IN
LOCAL GOVERNMENTS 1971 76 pp.

Wide variations in the basic costs of running local governments indicate that some localities are using more effective methods than others to provide services at lower costs.

PRIVATE SECTOR

IMPROVING PRODUCTIVITY: A DESCRIPTION OF SELECTED COMPANY
PROGRAMS (Series I) 1976 32 pp.

The first of a series of publications on company productivity programs. Describes programs in five companies chosen from different industries for diversity in size and type of operation. Focuses on how productivity efforts were organized and executed and on what was accomplished.

BACKHAUL IN FOOD DISTRIBUTION 1976 24 pp.

Backhauling -- permitting trucks to carry profitable loads on return trips -- would eliminate waste and increase productivity, according to food industry and government experts. Up to \$100 million in annual savings could possibly accrue from more efficient scheduling of the trucks used in transporting processed foods.

TECHNOLOGY APPLIED TO THE FOOD INDUSTRY (A PRELIMINARY REPORT) 1975 32 pp.

Poor communication between the food industry and the engineering community has prevented significant technological progress. Describes an innovative program to bring together engineers and food industry executives. Lists the significant technical barriers to improved efficiency in the supermarket, warehouse, and processing plant.

MEASURING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY 1975 104 pp.

Presents the views of influential industry, government, and academic authorities. Factors affecting productivity in various segments of the construction industry are isolated. Suggests possible solutions to the problems of productivity measurement in so diversified a sector of the economy.

PROCEEDINGS: CONFERENCE ON PRODUCTIVITY THROUGH ENGINEERING 1975 98 pp.

Proceedings of conference to help engineers determine which areas of productivity improvement are most responsive to engineering techniques and expertise.

KEEPING RAILROADS ON TRACK 1975 32 pp.

Based on Improving Railroad Productivity, the final report of the Task Force on Railroad Productivity. Discusses the many problems that beset the ailing railroad industry. Suggests innovations in corporate structure and freight handling procedures which would significantly improve rail service and make the railroads run profitably without large infusions of new capital or public monies.

LABOR-MANAGEMENT PRODUCTIVITY COMMITTEES IN AMERICAN
INDUSTRY 1975 60 pp.

Review of the limited experience in the United States with joint labor-management committees to deal with production and related problems. Begins with committees set up in the 1920s and 1930s; describes the joint committee effort during World War II and postwar experience with the Scanlon Plan and committees in government; reviews recent cooperative initiatives in basic steel, retail food, trucking, railroads, and other areas.

POINTERS FOR LABOR-MANAGEMENT COMMITTEES 1975 20 pp.

Discussion paper. Practical solutions to difficulties labor-management committees are likely to experience. Deals with how to start such committees, how members should function, and what they can hope to achieve.

EMPLOYMENT SECURITY AND PLANT PRODUCTIVITY COMMITTEE
TEN COORDINATING STEEL COMPANIES 1974 12 pp.

A presentation by I. W. Abel, President, United Steel Workers of America and Vice Chairman of the National Commission on Productivity and Work Quality. Describes labor and management experiences in the steel industry with the Employment Security and Plant Productivity Committees which have raised productivity levels and provided the foundation for the historic Experimental Negotiating Agreement of 1973.

IMPROVING RAILROAD PRODUCTIVITY 1973 332 pp.

Final report of the Task Force on Railroad Productivity. Concerned with railroads as transporters of freight. Considers some of the actions that the Federal government might take in concert with industry to restore the Nation's railroads and make them once more efficient, competitive, and profitable businesses.

PRODUCTIVITY IN THE FOOD INDUSTRY 1973 24 pp.

Summary of the report by the Food Industry Task Force. Suggests that the many opportunities for productivity increases can be realized only through the concerted efforts of all segments of the industry.

PRODUCTIVITY IN THE FISHING INDUSTRIES 1973 22 pp.

Based on the report by the Seafood Panel of the Food Industry Task Force. Discusses the decreasing production and productivity of the U.S. fishing industry, and outlines barriers to and opportunities for improvement.

PRIVATE SECTOR --
LABOR-MANAGEMENT COMMITTEES

RECENT INITIATIVES IN LABOR-MANAGEMENT COOPERATION
1976 96 pp.

Based on labor-management committee case histories which were presented during a series of conferences on recent initiatives. Participants included panels of workers and managers involved in cooperative activities. Focuses on practical day-to-day experiences in starting committees, and on the benefits and problems of cooperative efforts.

A PLANT-WIDE PRODUCTIVITY PLAN IN ACTION: THREE YEARS OF EXPERIENCE WITH THE SCANLON PLAN 1975 56 pp.

A brief description of the Scanlon Plan and its impact on productivity at DeSoto, Inc., a large manufacturer of paint, over a three-year period. Results showed productivity gains as high as 41 percent, and high levels of satisfaction with the plan on the part of both management and workers. Factors affecting worker acceptance of the plan are analyzed.

_____ Proceedings: Conference on Productivity Through Engineering
 _____ Keeping Railroads on Track
 _____ Improving Railroad Productivity
 _____ Productivity in the Food Industry
 _____ Productivity in the Fishing Industries

Private Sector--Labor-Management Committees

_____ Recent Initiatives in Labor-Management Cooperation
 _____ A Plant-Wide Productivity Plan in Action: Three Years of Experience
 With the Scanlon Plan
 _____ Labor-Management Productivity Committees in American Industry
 _____ Pointers for Labor-Management Committees
 _____ Employment Security and Plant Productivity Committee Ten Coordinating
 Steel Companies

To receive these publications, indicate copies desired, fill out (type or print) appropriate blank spaces below, including mailing label, and return to National Center for Productivity and Quality of Working Life, 2000 M Street, N.W., Washington, D.C. 20036.

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- _____ Conference on an Agenda for Economic Research on Productivity

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- _____ A Jurisdictional Guide to Productivity Improvement Projects, plus Quarterly Updates
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- _____ The Status of Productivity Measurement in State Government: An Initial Examination
- _____ Improving Municipal Productivity: Work Measurement For Better Management
- _____ So, Mr. Mayor, You Want to Improve Productivity
- _____ The Wingspread Conference: Productivity in State and Local Government
- _____ Improving Police Productivity: A Brief for Elected Officials
- _____ Opportunities for Improving Productivity in Police Services
- _____ Improving Productivity in Solid Waste Collection: A Brief for Elected Officials
- _____ Opportunities for Improving Productivity in Solid Waste Collection
- _____ Improving Productivity and Productivity Measurement in Local Governments

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- _____ Technology Applied to the Food Industry (A Preliminary Report)
- _____ Measuring Productivity in the Construction Industry

BLS Publications on Productivity and Technology

Report 461

I. Productivity studies

A. Concepts and Techniques of Productivity Measurement

1. "The Significance of Measures of Productivity," by Jerome A. Mark, in *Proceedings of the Conference on Productivity Through Engineering*, a conference sponsored by the National Commission on Productivity and Work Quality and the Engineers Joint Council, New York, N.Y., May 1975, pp. 25-31.
2. "Productivity Measurements: Accomplishments and Problems," by Jerome A. Mark, before the American Statistical Association and the Industrial Relations Research Association, San Francisco, June 1974.
3. "Meanings and Measures of Productivity," by Jerome A. Mark, *Public Administration Review*, November-December 1972, pp. 747-752.
4. *Meaning and Measurement of Productivity*. BLS Bulletin 1714, a report prepared for the National Commission on Productivity by the Bureau of Labor Statistics, 1971.
5. "Output Per Man-hour Measures: Private Sector," reprint of Chapter 25 of the *Handbook of Methods for Surveys and Studies*, BLS Bulletin 1711, 1971. Describes the methods used to derive productivity measures.
6. "Output Per Man-Hour Measures: Industries," reprint of Chapter 26 of the *Handbook of Methods for Surveys and Studies*, BLS Bulletin 1711, 1971. Describes the methods used to produce BLS industry productivity measures.
7. "Industry Productivity Measurement in the United States," a paper prepared for the Statistical Office of the United Nations, January 1970.
8. *Industry Productivity Projections: A Methodological Study*, by Benjamin P. Klotz, prepared for the National Commission on Tech-

nology, Automation, and Economic Progress by the Bureau of Labor Statistics, 1966.

9. "Technical Note: Industry Indexes of Output Per Man-Hour," by Jerome A. Mark, *Monthly Labor Review*, November 1962, pp. 1269-73.

10. "Which Productivity? Perspective on a Current Question," by Solomon Fabricant, *Monthly Labor Review*, June 1962, pp. 609-13. Discusses alternative measures of productivity.

B. Productivity Trends in the Private Economy and Major Sectors

1. *Productivity and Costs in the Private Economy*. 1947 to the present. Quarterly and annual.
2. *Productivity and Costs in Nonfinancial Corporations*. 1958 to the present. Quarterly and annual.
3. *Trends in Output per Man-Hour in the Private Economy, 1909-1958*, BLS Bulletin 1249, 1959.

C. Productivity Trends in Individual Industries

1. *Productivity Indexes for Selected Industries, 1975 Edition*, BLS Bulletin 1890, 1976. Includes the following industries:

SIC Code	Industry	Latest year
	Mining	
1011	Iron mining, crude ore	1974
1011	Iron mining, useable ore	1974
1021	Copper mining, crude ore	1974
1021	Copper mining, recoverable metal	1974
111, 121	Coal mining	1974
121	Bituminous coal and lignite mining	1974
	Manufacturing	
203	Canning and preserving	1973
2041	Flour and other grain mill products	1974
205	Bakery products	1974
2061, 2062, 2063	Sugar	1974

D. Productivity Trends in the Federal Government

1. "Measuring Productivity in the Federal Government," by Charles W. Ardolini and Jeffrey Hohenstein, *Monthly Labor Review*, November 1974, pp. 13-20.
2. "Developments in Measuring Productivity in the Federal Sector," by Jerome A. Mark and Charles W. Ardolini, in *Proceedings of the American Statistical Association, Business and Economics Statistics Section*, 1974, pp. 236-245.
3. "Progress in Measuring Productivity in Government," by Jerome A. Mark, *Monthly Labor Review*, December 1972, pp. 3-6.
4. "Better Federal Coverage Needed to Improve National Measurement," by Jerome A. Mark, *Defense Management Journal*, October 1972, pp. 12-15.

E. Productivity and Other Economic Trends

1. *Current Developments in Productivity, 1973-74*, by Jerome A. Mark, BLS Report 436, 1975.
2. "Productivity and costs in the private economy, 1974," by Jerome A. Mark, *Monthly Labor Review*, June 1975, pp. 3-8.
3. *Productivity and the Economy*, BLS Bulletin 1779, 1973. A chart-book investigating productivity trends and their relation to other economic trends.
4. "Productivity Trends and their Implications," by Jerome A. Mark, Symposium on Productivity, University of Southern California, Sacramento, California, November 1972.
5. "Productivity and Unit Labor Costs in Export and Import-Competing Industries, 1958-68," in *United States International Economic Policy in an Interdependent World*, papers submitted to the Commission on International Trade and Investment Policy, Compendium of Papers, Vol. 1, July 1971, Washington, D. C., pp. 507-34, (3-volume set).
6. *Productivity in the Railroad Industry*, BLS Report 377, 1970.
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8. "Wage-Price Guidepost Statistics: Problems of Measurement," by Jerome A. Mark, before the American Statistical Association, Pittsburgh, Pennsylvania, August 1968.
9. "Sector Changes in Unit Labor Costs," by Leon Greenberg and Jerome A. Mark, a reprint from *The Industrial Composition of Income and Product*, New York: National Bureau of Economic Research, 1968.
10. "Productivity in Manufacturing," by Martin Ziegler, *Monthly Labor Review*, October 1967, pp. 1-5. Relates trends in unit labor costs to changes in the business cycle.
11. *Disemployment of Labor at the Establishment Level*, by Benjamin P. Klotz, a report prepared for the National Commission on Technology, Automation, and Economic Progress, 1966.

II. Technology studies

A. Case Studies

1. "A Study of the Impact of Office Automation in the IRS," by Herman J. Rothberg, *Monthly Labor Review*, October 1969, pp. 26-30.
2. *Manpower Planning for Technological Change-Case Studies of Telephone Operators*, BLS Bulletin 1574, 1968. Also, "Changing Manpower Needs in Telephone Offices," by Audrey Freedman and Edgar Weinberg, *Monthly Labor Review*, February 1968, pp. 56-58.
3. *Job Redesign for Older Workers, Ten Case Studies*, BLS Bulletin 1523, 1967. Also, "Job Redesign for Older Workers: Case Studies," by Herman J. Rothberg, *Monthly Labor Review*, January 1967, pp. 47-51.
4. *Manpower Planning to Adapt to New Technology at an Electric and Gas Utility*, BLS Report 293, 1965. Also, "Manpower Planning at an Electric and Gas Utility," by Richard W. Riche, *Monthly Labor Review*, August 1965, pp. 965-67.

B. Industry Studies

1. *Technological Change and Manpower Trends in Five Industries* (Pulp and paper, hydraulic cement, steel, aircraft and missiles, and wholesale trade), BLS Bulletin 1856, 1975.

C. Innovation Studies

1. *Computer Manpower Outlook*, BLS Bulletin 1826, 1974.
 2. *Outlook for Computer Process Control*, BLS Bulletin 1658, 1970. Also, "Manpower Implications of Computer Control in Manufacturing," by Arthur S. Herman, *Monthly Labor Review*, October 1970, pp. 3-8.
 3. "Manpower Implications of Computer Process Control in Rolling Mills and Finishing Operations," by Jerome A. Mark, Economic Community for Europe, First Seminar of Steel Committee, Budapest, 1970.
 4. *Outlook for Numerical Control of Machine Tools*, BLS Bulletin 1437, 1965. Also, "Prospects for Numerical Control of Machine Tools," by John J. Macuti, *Monthly Labor Review*, April 1965, pp. 403-6.
- ### D. General Studies
1. *The Revised Workweek: Results of a Pilot Study of 16 Firms*, BLS Bulletin 1846, 1975.
 2. *Improving Productivity: Labor and Management Approaches*, BLS Bulletin 1715, a report prepared for the National Commission on Productivity, 1971. Presents examples of formal efforts by management and labor to improve productivity.
 3. "Technological Change," reprint of Chapter 27 of *The Handbook of Methods for Surveys and Studies*, BLS Bulletin 1711, 1971. Explains how the BLS studies technology.
 4. "Technological Change and Education," by Edgar Weinberg, in *Encyclopedia of Education*, MacMillan Company, New York, 1971.
 5. "Some Manpower Implications," by Edgar Weinberg, in *Automation Management: The Social Perspective*, Second Annual Georgia Reliance Symposium, Athens, Georgia, 1970.
 6. "The City and the Computer," by Edgar Weinberg, *Occupational Outlook Quarterly*, Spring 1969, pp. 24-25.
 7. "Trends in Service Sector Employment," by Edgar Weinberg, in *Human Resource Development*, Ames, Iowa: Iowa State University Press, 1967, pp. 56-62.

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EXCERPTS FROM

Productivity and Technological Innovation

Selected
Information
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John K. Tabor
Under Secretary

Tilton H. Dobbin
Assistant Secretary for
Domestic and International Business

Samuel B. Sherwin
Deputy Assistant Secretary
for Domestic Commerce

March 1975

January 1975

List of Federal Productivity Project Publications

- I. Copies of the following publications are available from Brian Usilaner, Joint Financial Management Improvement Program, 666 11th Street NW Suite 705, Washington, DC 20001. Publications marked with an asterisk (*) are no longer available.

Report on Federal Productivity, Volume 1, Productivity Trends, FY 1967-1973 (June 1974)

Report on Federal Productivity, Volume 2, Productivity Case Studies (June 1974)

Report on Federal Productivity, Supplement to Volume 1, The Measurement Data Base (October 1974)

Phase III Summary Report, Measuring and Enhancing Productivity in the Federal Government (June 1973)

Special Report #1, Volume 1, The Permanent Measurement System: Methods, Measures, Results (December 1973)

Special Report #1, Volume 2, The Permanent Measurement System: Methods, Measures, Results: Description of Federal Organizational Elements and Outputs for Fiscal Year 1972 (October 1973)

Special Report #2, Case Studies in Federal Productivity Change FY 1967-72 (November 1973)

*Special Report #3, Volume 1, Special Studies of Measurement Problems: Measuring Research and Development and Grant Administration Programs (October 1973)

Special Report #3, Volume 2, Special Studies of Measurement Problems: Improving Work Measurement Systems in the Federal Sector (October 1973)

Special Report #4, Analysis of Productivity -- Enhancing Capital Investment Opportunities (September 1973)

Special Report #5, Human Factors in Organizational Productivity (October 1973)

Proceedings of the Quality Measurement Workshop (December 1973)

- 2 -

*Measuring and Enhancing Productivity in the Federal Sector (June 1972)

Federal Productivity: Methods, Measurements, Results (August 1972)

*Guidelines for Evaluating Work Measurement Systems in the Federal Government (July 1972)

*Auditing: Operational, Management, Performance, Effectiveness (June 1972)

* * *

- II. Copies of "Measuring Productivity in the Federal Government," Monthly Labor Review (November 1974) are available from Jeff Hohenstein, Bureau of Labor Statistics, Room 205, National Association of Letter Carriers Building, 100 Indiana Avenue, N.W., Washington, D. C. 20212

* * *

- III. Other related information may be available from:

Ms. Elsa Porter
Civil Service Commission
Room 5455
1900 E Street, N.W.
Washington, D. C. 20415

Mr. Gordon Yamada
General Services Administration
Room 6205 - AMM
19th and F Street, N.W.
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APPENDIX E. SAMPLE PRODUCTIVITY NEWSLETTERS



TIPS ON PRODUCTIVITY IMPROVEMENT IMPORTANCE OF MEASUREMENT

A company's productivity performance may be enhanced by a program of measurement. This prospect has encouraged many companies to adopt measurement systems over the years. Only a small number of firms are as yet tracking their own performance, but new circumstances (such as intensifying international competition to meet rising oil costs) promise a large increase in their number.

Productivity measurement serves as a tool for productivity enhancement in four ways. First, the installation of a measurement system and the discussion preceding it heighten staff awareness of the importance of raising output per unit of input for the maintenance of profitability. Second, observed changes in the numbers often have diagnostic value, pointing to bottlenecks and other impediments to superior company performance. Third, the changes in the numbers also allow assessment of the consequences of intended remedial actions. Fourth, continuing discussion of the validity of the measurements promotes productivity-consciousness, contributing to an atmosphere congenial to operational as well as statistical improvement.

Even crude initial productivity estimates can prove beneficial to a company's performance. Their availability and use provide occasion for serious communication between management and employees on matters of mutual concern. In the course of such interaction, illuminating insights are often generated and transmitted.

However conscientiously a measurement program is carried out, management needs to show sophistication and reasonableness in interpreting the results. One should keep in mind that the numbers generated, while informative, can be improved upon and should not be accepted as a definition of the problem. Obviously, many pertinent features of a complex business environment are bound to escape reflection in any set of statistics. Employees must be convinced of the fairness of management in the interpretation of the numbers and of the willingness of management progressively to upgrade the quality of the numbers.

In setting up a measurement system, a company must first consider the preferred scope and periodicity of the figures. It is better to concentrate first on critical activities (operations, departments, plants, or divisions) than to strive for comprehensive company coverage from the beginning. It is better to test various plausible approaches to measurement and to make required adjustments before deciding on periodicity.

The cycle-time of production, incidentally, has a bearing on the frequency of measurement as well as on the choice of the output indicator. If a productivity measure is wanted monthly or quarterly for, say, a shipyard, it is desirable to redefine a ship as a sum of more or less homogeneous "subproducts" that could be made in a month or a quarter.

A company that wishes to monitor its productivity may also wish to track related variables. Thus, a company measuring its productivity in terms of output per man-hour may find it advantageous to have correlative information on unit labor cost.

Whether a company has modest or ambitious measurement schemes, its strategy has to take account of three interdependent elements of quantification: concepts, data, and methods of measurement. The definition of productivity as output per unit of input embraces many eligible specific concepts; thus, output may be viewed as gross or net, and input may refer to labor, capital, energy, materials, or any combination of these. Data are frequently limited in quantity and need to be adapted to uses for which they were not originally compiled. Details of the measurement process, such as the choice of weights for the aggregation of component outputs or component inputs or the choice of a formula for averaging, are best settled with regard to the preferred concepts and the available data.

Adequate provision needs to be made for (1) critical review and (2) progressive refinement of productivity measures to assure that they remain tools rather than degenerate into toys. Both activities are legitimate features of a well-conceived measurement program and accordingly ought to be incorporated in the design. They are essential for fulfilling the promise of productivity measurement as a mode of motivation of personnel, diagnosis of operations, and timely remedial action in a dynamic, competitive business world.

The Department of Commerce has cosponsored seminars and workshops intended to help organizations help themselves by monitoring their own performance. More activity along these lines, with regional offices taking part, is under study. Company interest in participating in such a program should be registered with your area DOC Field Office. Further information on the subject may be obtained from the same source. Meanwhile, companies wishing to explore the requirements and benefits of measurement systems on their own may find the appended bibliography helpful.

Further reference: *

J. J. Carr, "Measuring Productivity", Arthur Andersen & Company, 1973.

D. L. Cocks, "The Measurement of Total Factor Productivity for a Large U. S. Manufacturing Corporation," Business Economics, September 1974.

- C. E. Craig and R. C. Harris, "Total Productivity Measurement at the Firm Level," Sloan Management Review, Spring 1973.
- L. Greenberg, A Practical Guide to Productivity Measurement, Bureau of National Affairs, Washington, 1973.
- J. W. Kendrick and D. Creamer, Measuring Productivity: Handbook with Case Studies, Studies in Business Economics, No. 89, Conference Board, New York, 1965.
- W. R. Sherrard, "Labor Productivity for the Firm: A Case Study", Quarterly Review of Economics and Business, Spring 1967.
- I. H. Siegel, "Measuring Productivity", in the "Keep America Competitive" section inserted into Purchasing, Metalworking Economics, Plastics World, and other Canners (Conover-Mast) trade publications of April 1971.

* This listing is not to be considered complete and the inclusion of publication is not considered a Department endorsement.

THE DEFENSE PRODUCTIVITY NEWSLETTER

Defense Industrial and Management Engineering Office, Cameron Station, Alexandria, Va. 22314

VOLUME 1, NUMBER 1

SEPTEMBER 1975

SECRETARY CLEMENTS FORMALIZES DOD PRODUCTIVITY PROGRAM

Department of Defense policies and responsibilities for Defense-wide Productivity Program were issued on August 4 with the signing of DoD Directive 5010.31 by Deputy Secretary of Defense William P. Clements, Jr. The new directive, titled "Productivity Enhancement, Measurement, and Evaluation - Policies and Responsibilities" consolidates the interrelated productivity guidance formerly contained in OASD(I&L) memorandum on productivity dated August 20, 1973, DoD Directive 5010.15, "Defense Integrated Management Engineering System (DIMES)," and DoD Instruction 7045.11, "Improvement and Use of Output Information in DoD Planning, Programming, and Budgeting System."

The directive requires priority emphasis on productivity at all organizational echelons throughout DoD, and states that productivity efforts and reporting will be an integral element of all resource management and budgeting systems operated in the DoD.

Each DoD component has been directed to sustain a department/agency-wide productivity program which includes a systematic approach to enhancement, measurement, and evaluation; the prudent use of all available means, disciplines, and techniques to improve productivity; and aggressive methods and standards improvement effort; a systematic approach to capital investment planning and financing; and the development and use of productivity trend data in resource management and control.

Overall responsibility for the program has been assigned to the Assistant Secretary of Defense (Installations and Logistics). It is the responsibility of the Defense Comptroller to ensure that these efforts are integrated in DoD resource management systems and that DoD accounting systems can be utilized to accumulate productivity data. The Assistant Secretary of Defense (Manpower and Reserve Affairs), is responsible for guidance on personnel motivation techniques and the use of productivity data in determining staffing requirements and patterns.

POLICY AND GUIDANCE

PRODUCTIVITY PROGRAM GUIDELINES AND OPERATING INSTRUCTIONS ISSUED BY ASD(I&L)

Dr. John J. Bennett, Acting Assistant Secretary of Defense (Installations and Logistics) has issued operating guidelines and reporting instructions for the DoD Productivity Program in DoD Instruction 5010.34, dated August 4, 1975. The instruction provides minimum criteria to be followed by DoD components in the areas of methods and standards, capital investment planning and financing, and productivity evaluation. It also sets forth minimum reporting requirements necessary to provide productivity data for the Office of the Secretary of Defense and to comply with government-wide productivity reporting requirements.

The introduction paragraph of the instructions states that "Organizations

must be both (a) effective -- accomplish the right things in the right quantities, at the right times and (b) efficient - accomplish the right things with the lowest possible expenditure of resources," and cites optimum productivity growth as the primary objective of the DoD program.

The instruction, applicable to all military departments and defense agencies, requires that the head of each DoD component establish productivity improvement goals for his department/agency, advise the Secretary of Defense by October 31 of these established goals, and monitor progress to ensure achievement of the goals.

The instruction specifically highlights two major areas for enhancing productivity; systematic methods improvement review and appropriate use of labor performance standards, and the timely identification and funding of fast payback capital investments. Guidance for insuring effective applications in these two areas has been provided. It also established a functional approach to productivity measurement and evaluation, clearly stating that functional managers are responsible for productivity improvements in their respective areas. Service/agency implementation plans and progress will be reported in future issues of the Newsletter.

* * * * *

SECDEF IS BRIEFED ON PRODUCTIVITY
IN DOD SUPPORT STRUCTURE

As a follow-up to the recent actions by Defense on productivity, Secretary of Defense James R. Schlesinger was briefed by the staff of the Assistant Secretary of Defense (Program Analysis and Evaluation) on manpower productivity in DoD's support structure. In a memorandum to Secretary Schlesinger, Assistant Secretary Leonard Sullivan, Jr., highlighted the past record of Defense in improving productivity but stressed the need for a dynamic and well integrated program to maintain this growth.

In explaining this need, Secretary Sullivan estimated that each 1% increase in DoD productivity results in \$200 million savings. He stated that since wages and salaries are based by law on the principle of comparability with private sector workers, DoD will be

paying its own workers for productivity increases realized in the private sector. He pointed out that DoD productivity must therefore increase to match private sector trends just to maintain current levels of real program value.

In the briefing, the following were singled out as essential elements to a successful DoD program:

- A comprehensive and consistent productivity measurement and evaluation system covering all major functions of the support structure
- Greater emphasis on and local activity capability to invest capital in productivity enhancing projects.
- Expanded efforts to improve work processes and methods and to eliminate unnecessary functions.
- Worker motivation programs.

PRODUCTIVITY ENHANCEMENT

NEW CHANGES IN FUNDING PROMOTE FINANCING FOR FAST PAYBACK CAPITAL INVESTMENTS

By memorandum dated June 5, 1975, Deputy Secretary of Defense William P. Clements, Jr., advised the Secretaries of the Military Departments and the Directors of the Defense Communications Agency and the Defense Supply Agency of a significant revision to DoD financial regulations which should result in substantial productivity improvement in industrially funded activities. Under the new guidelines industrial fund managers can use their funds to finance tools and equipment costing up to \$100,000 so long as the costs can be recovered from savings in increased efficiency within two years. This flexibility will eliminate long budget lead times in procuring equipment which promises early returns from investments.

Prior to this change, industrial funds could only be used to finance items costing \$1,000 or less. DoD components must obtain approval of their revised implementation procedures from the ASD(Comptroller).

APPENDIX F. SAMPLE PRODUCTIVITY TRAINING COURSES
AND SEMINARS

Productivity Improvement and Related Courses
Conducted by the
U.S. Civil Service Commission

I. Making Better Use of Productivity Measurement Systems.

A. Executive Orientation in Productivity Measurement

This new course will be conducted in FY 1974 and will be aimed at informing executive level Federal, State and local officials how productivity measures can be used to evaluate and improve organizational performance.

B. Effectiveness Measurement Systems

This new course will be conducted for the first time in FY 1974. It will teach how to define goals and objectives, develop and install measurement systems, track program performance and evaluate performance against planned objectives.

C. Productivity Management

This course teaches how to determine and measure unit cost and time requirements for repetitive and non-repetitive tasks, how to establish productivity indices, and how to install reporting systems for gathering productivity data.

II. Making Better Use of Capital Investment to Improve Productivity.

A. Capital Resource Management

This course teaches government officials how to identify the capital cost associated with an organization's products, how to analyze the potential for capital investment in the delivery of these products or services, how to forecast short and long-range productivity gains related to the introduction of capital equipment, and how to develop justifications for making capital investments which will improve productivity.

III. Making Better Use of Work and Systems Design Techniques to Improve Productivity.

A. Value Analysis

This course teaches how to identify the function of a management system, service or procedure; how to establish a value for that function; and how to provide that function at the lowest cost.

The student learns value analysis methods by applying the techniques taught in class to an actual agency problem area. This approach is most effective when an agency sends an interdisciplinary team which is thoroughly familiar with the system or procedure to which value analysis techniques are to be applied.

B. Paperwork Flow Analysis and Improvement

This course teaches how to analyze and improve paperwork flow in an organization.

C. Network Techniques for Project Management

This course teaches how to apply PERT, Critical Path Method, and specialized Gantt charting to the planning, tracking and evaluation of projects.

D. Workshop in Process Flow Charting

This course teaches how to flow chart work in order to improve work flow and effectiveness.

IV. Making Better Decisions on Alternative Methods of Improving Productivity.

A. Cost Benefit Workshop

This course teaches how to identify the cost and benefits involved in several alternative courses of action by employing such analytic techniques as systems analysis, discounting and cost benefit ratios.

B. Cost Estimating Techniques

This course teaches how to determine future costs of alternative courses of action by using improvement curves, index numbers, correlation and regression analysis and time series.

C. Economic Investment Analysis

This course teaches how to systematically allocate scarce resources in an efficient and effective manner by using economic analysis. It also teaches how economic analysis can be applied to on-going programs to improve effectiveness.

V. Other courses on productivity are also available from the Federal Executive Institute, Rt 29 North, Charlottesville, Virginia 22903

NATIONAL CENTER FOR PRODUCTIVITY AND QUALITY OF WORKING LIFE

SEMINAR ON
PRODUCTIVITY IMPROVEMENT THROUGH MEASUREMENT

Cosponsored by the U. S. Department of Commerce,
U. S. Department of Labor, and National Science Foundation

Statler Hilton Hotel
Washington, D. C.
June 23, 1976

8:30 a.m. Registration (Congressional Room) .

9:00 a.m. Welcome and Introductions

Keynote Speech
Donald C. Burnham, Director-Officer,
Westinghouse Electric Corporation

Measurement: Techniques and Uses

Measuring Company Productivity
Irving H. Siegel, Advisor to Director,
Bureau of Domestic Commerce

Measuring Industry Productivity
Jerome A. Mark, Assistant Commissioner for
Productivity and Technological Development,
Bureau of Labor Statistics

Questions

10:30 a.m. Break

Examples of Measurement

Productivity Measurement at ALCOA
M. E. Gantz, Jr., Executive Vice President,
Mill Products, Aluminum Company of America

NAWGA's Warehousing Productivity Measurement Program
Gerald E. Peck, Executive Vice President,
National-American Wholesale Grocers' Association

Questions

12:00 p.m. Luncheon

Concluding Remarks
Donald C. Burnham

2:00 p.m. Workshops to be formed after luncheon for those
who wish to confer with speakers.

APPENDIX G. SAMPLE PRODUCTIVITY RESEARCH PROJECTS

NATIONAL SCIENCE FOUNDATION RESEARCH APPLIED TO NATIONAL NEEDS (RANN) PROGRAM ON PRODUCTIVITY MEASUREMENT

RANN supports research in three major areas of productivity measurement--national economic measures, measures for the delivery of urban services and productivity measurement systems for administrative services.

The program on productivity measurement systems for administrative services was developed to deal with the changing nature of the U.S. production system. The increasing use of technology in the direct production of goods and services and on the changing nature of organizational structures has resulted in an increased use of resources in nonproduction activities. This trend is reflected in employment statistics. For example, between 1950 and 1970, professional and technical workers increased from 8.7 percent of the workforce to 14.7 percent; managers and officials from 8.9 percent of the workforce to 10.5 percent; and clerical and kindred from 12.3 percent of the workforce to 17.4 percent. Many companies report similar changes. Indeed, in most industries about two thirds of the employees work in nonproduction areas.

The purpose of the RANN program in productivity measurement systems in administrative services is to develop and to test measurement systems in this area. To date, seven awards have been made and the research is in progress. Attached are summaries of the projects which have been awarded.

NATIONAL SCIENCE FOUNDATION

PROJECT
SUMMARY

NSF GRANT NO

NAME OF INSTITUTION (NSF DIRECTORY NAME)		ADDRESS OF INSTITUTION (INCLUDE BRANCH/CAMPUS & COMPONENT)	
Michigan State University		Department of Management East Lansing, Michigan 48824	
PRINCIPAL INVESTIGATOR	SOCIAL SECURITY NO.	DIVISION (OFFICE) AND DIRECTORATE	
Robert M. Monczka		Advanced Productivity Research & Technology	
		SECTION	
		Productivity Measurement	
PROPOSAL NUMBER		PROGRAM	
APR75-20557		Public Policy and Economic Productivity	
TITLE OF PROJECT			
"Research on Productivity Measurement Systems for Administrative Services: Purchasing Management"			
SUMMARY OF PROPOSED WORK (LIMIT TO 25 PICA OR 18 ALIVE TYPEWRITTEN LINES)			
<p>This research will define the current state-of-the-art in productivity measurement in purchasing in U.S. organizations. Improved productivity measurement systems for the purchasing function will be developed from the information gained from the research. Leading organizations in the development and implementation of productivity measurement systems in purchasing have been identified in the industrial, retail and federal sectors and will participate in the field research. These sectors were chosen for study because of their contribution to the Gross National Product and magnitude of purchase expenditures. Data will be collected about the productivity measurement system, the productivity measures, the behavioral impact of the system, the effectiveness/ineffectiveness of the productivity measures, and the internal and external environments from the approximately 14 sites visited by a combination of interviews, and questionnaires, the collection of internal documentation, and records examination. The data analysis will consist of determining the effectiveness/ineffectiveness of productivity measures using selected criteria and these measures will then be compared across selected external, internal, and productivity measurement system dimensions. These comparisons will be across each organization, and within and across the sectors being studied; relationships to and causality of effective/ineffective productivity measurement systems will be looked for. Results of the study will be disseminated by mailings to top executives and purchasing managers of the top 500 industrial organizations, monograph publication, a user conference and seminars, notices about study in the Bulletins of the National Association of Purchasing Management and the National Institute of Government Purchasing, presentation of papers at academic and professional meetings, and publication in periodicals.</p>			

Effective Date: October 1, 1975

Duration: 15 months

NATIONAL SCIENCE FOUNDATION

PROJECT
SUMMARY

NSF GRANT NO.

NAME OF INSTITUTION (SEE DIRECTORY NAME)		ADDRESS OF INSTITUTION (INCLUDE BRANCH/CAMPUS IF APPLICABLE)	
Georgetown University		Public Services Laboratory 37th and O Streets Washington, D.C. 20057	
PRINCIPAL INVESTIGATOR	SOCIAL SECURITY NO.	DIVISION (OFFICE) AND DIRECTORATE	
Selma J. Mushkin		Advanced Productivity Research & Technology	
		SECTION	
		Public Policy & Economic Productivity	
PROPOSAL NUMBER		PROGRAM	
APR76-08199		Productivity Measurement	
TITLE OF PROJECT			
Productivity Measurement Systems for Administrative Services: Personnel-Administration and Training			
SUMMARY OF PROPOSED WORK (LIMIT TO 12 PICA OR 16 ELITE TYPEWRITTEN LINES)			
<p>This project is designed to find out what difference the use of productivity measurements makes in personnel systems and how the management of the personnel system contributes to improvement in the quantity and quality of city services.</p> <p>The research will proceed in 3 stages. First, statistical data on manpower and fiscal effort will be obtained in 8 medium-sized cities selected from among those with a history of productivity measurement effort. Indicators of the quality of the personnel management function will be related to measures of productivity of the delivery of services.</p> <p>Second, 4 of these cities selected on the basis of personnel management methods and general fiscal characteristics, will be intensively reviewed and rated on their personnel management system, including recruitment, selection, classification, pay and hours of work, performance appraisal, training, retirement, collective bargaining, and intrinsic motivational climate. Productivity measures of the personnel system, the above functions, and of general services, along with per capita costs of public services, will be obtained and an estimate made of cost effectiveness of the system. Evaluative case studies will be written for each of these cities.</p> <p>Third, a detailed research design for field experimentation on productivity measurement in administrative services will be developed.</p>			

Effective Date: July 1, 1976
Duration: 12 months

NATIONAL SCIENCE FOUNDATION

PROJECT
SUMMARY

NSF GRANT NO

NAME OF INSTITUTION (NSF DIRECTOR'S NAME)		ADDRESS OF INSTITUTION (INCLUDE BRANCH/CAMPUS & COMPONENT)	
ABT Associates Inc.		55 Wheeler Street Cambridge, Massachusetts 02138	
PRINCIPAL INVESTIGATOR	SOCIAL SECURITY NO	DIVISION (OFFICE) AND DIRECTORATE	
Peter Merrill		Advanced Productivity Research & Technology SECTION	
PROPOSAL NUMBER		Productivity Measurement	
APR75-20564		PROGRAM	
TITLE OF PROJECT		Public Policy and Economic Productivity	
"Research on Productivity Measurement Systems for Administrative Services: Budget and Management Analysis"			

SUMMARY OF PROPOSED WORK (LIMIT TO 12 PICA OR 16 SLIDE TYPEWRITER LINES)

The proposal objective is to develop, test, and disseminate new and improved techniques for measuring the productivity of the budgeting and management analysis function in 3 types of public institutions: state government, hospital and university. The research design includes identifying the inputs and outputs for the budgeting and management analysis function in each institution and developing an organizational model of the production processes. The model will be used to develop several basic measures of productivity including: a work measure involving primary output per man-hour, total output with labor costs as weights, total output with unit costs as weights, and total output with shadow prices as weights. Shadow prices will be estimated by both revealed preference and production possibility surface methods. Indices will be constructed and monitored in the participating organization.

Effective Date: December 1, 1975
Duration: 10 months

APPENDIX H. POLICY STATEMENT FOR FEDERAL
PRODUCTIVITY PROGRAM

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

OCT 23 1974

MEMORANDUM TO HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

SUBJECT: Federal Productivity Program

Vigorous efforts to improve productivity are essential to counter the impact of inflation and provide better service to the public within the limits of available funds.

My memorandum of July 9, 1973, authorized continuance of an annual review and report on the productivity of Federal workers. The results of the productivity review during the last year have been incorporated in a Report on Federal Productivity issued by the Joint Financial Management Improvement Program. Copies of this report have been sent to all Departments and Agencies, as well as to the President and the Congress.

The report provides substantial evidence of the increasing efficiency of the Federal workforce and indicates that several agencies are using productivity measures, in conjunction with other measures of performance, as an effective part of their management process. However, we must do more.

I urge each of you to personally stress the goals of the Federal Productivity Program and to seize every opportunity for further productivity improvements. By intensifying our efforts, we can manage our activities in a manner that permits us to better serve the American people.

Moreover, we want to share the knowledge gained in the Federal Program with officials of State and local governments. As productivity is increased throughout all levels of government, Americans will receive maximum returns for their tax dollars.


Roy L. Ash
Director

June 1975



Annual Report To The President And The Congress

Productivity Programs In The Federal Government FY 1974

Volume One: Current Efforts And Future Prospects

Joint Financial Management
Improvement Program

FOREWORD

This is the second annual report prepared by the Joint Financial Management Improvement Program (JFMIP) on productivity in the Federal Government. It has been prepared in accordance with the responsibilities assigned JFMIP in a July 9, 1973, memorandum from the Director of the Office of Management and Budget establishing a continuing Federal productivity program.

This document, Volume I, presents data on Federal productivity trends for FY 1967-74 and the reasons for productivity increases and decreases. It contains information on productivity in other sectors of the nation's economy. It also comments on activities now underway and future needs and plans for productivity improvement.

Volume II contains case studies illustrating some of the many efforts made by specific organizations to measure and improve productivity.

Major staff work on this report was performed by Edwin Soniat, Joseph Myers, and Beverly Reece under the leadership of Dr. Brian Usilaner, Assistant Director, JFMIP. Valuable ideas and comments were received from staff members of the several agencies that provide the combined leadership for the Federal productivity program--the Bureau of Labor Statistics, the General Accounting Office, the Office of Management and Budget, the Civil Service Commission, the General Services Administration, and the National Commission on Productivity and Work Quality. The report would not have been possible without the help of the productivity principals and other officials of the 48 Federal agencies which supplied measurement data and other information on their productivity programs.

Many lessons have been learned from the productivity efforts of the last few years. One is that productivity improvement is not achieved by fiat or exhortation. It requires careful planning, leadership and support. The current high level of public and official interest in productivity provides a unique opportunity to build on the past progress and make productivity a "way of life" for all Federal agencies. We hope substantial progress can be made toward that goal during the coming year.

Donald C. Kull

Donald C. Kull, Executive Director
Joint Financial Management
Improvement Program
June 1975

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APPENDIX J. PRODUCTIVITY MEASUREMENT DATA ON 26 U.S. NAVY SHIPS

PACFLT EMRM PROGRAM SHIPS FORCE WEEKLY MAINTENANCE SUMMARY

(REV 10/10/75)

USS _____

WORK CENTER _____

FOR WEEK ENDING MIDNIGHT SUNDAY _____
(DAY) (MONTH) (YEAR)

SECTION A. PM (PREVENTIVE MAINTENANCE)

SCHEDULED PMS MR'S		PMS MR'S FULLY COMPLETED		PMS MRS PARTIALLY COMPLETED		MANHOURS EXPENDED ON PMS	OTHER PM ACTIONS (NOT PMS)	
NUMBER		NUMBER		NUMBER			NUMBER	MANHOURS
D AND W	OTHER	D AND W	OTHER	D AND W	OTHER			

SECTION B. BREAKDOWN BY REASON OF PM ACTIONS/REQUIREMENTS NOT COMPLETED

SINGLE MAJOR REASON FOR NON OR INCOMPLETE ACCOMPLISHMENT	NUMBER
1. LACK OF FUNDING FOR NEEDED PARTS OR MATERIALS	
2. PARTS OR MATERIALS NOT AVAILABLE WHEN NEEDED	
3. SHIPS FORCE WORK BACKLDG, DTHR REQUIREMENTS ON SHIPS FORCE	
4. PERSONNEL PRESENTLY DN BDARD LACKING IN NEEDED TRAINING DR EXPERIENCE	
5. OTHER	

SECTION C. CM (CORRECTIVE MAINTENANCE)

NEW S/F ITEMS ADDED TO WC EDL WL		CM ACTIONS COMPLETED		CM ACTIONS STARTED BUT NOT COMPLETED	
NUMBER		NUMBER	MANHOURS EXPENDED	NUMBER	MANHOURS EXPENDED

SECTION D. BREAKDOWN BY REASON OF SHIPS FORCE CORRECTIVE MAINTENANCE ITEMS NOT COMPLETED, OR IF STARTED, NOT PROGRESSING SATISFACTORILY

SINGLE MAJOR REASON FOR NON OR INCOMPLETE ACCOMPLISHMENT	NO OF M.A.
1. LACK OF FUNDING FDR NEEDED PARTS OR MATERIALS	
2. PARTS OR MATERIALS NOT AVAILABLE WHEN NEEDED	
3. SHIPS FORCE WORK BACKLDG/OTHER REQUIREMENTS ON SHIPS FORCE	
4. PERSDNNEL PRESENTLY ON BDARD LACKING IN NEEDED TRAINING OR EXPERIENCE	
5. OTHER	

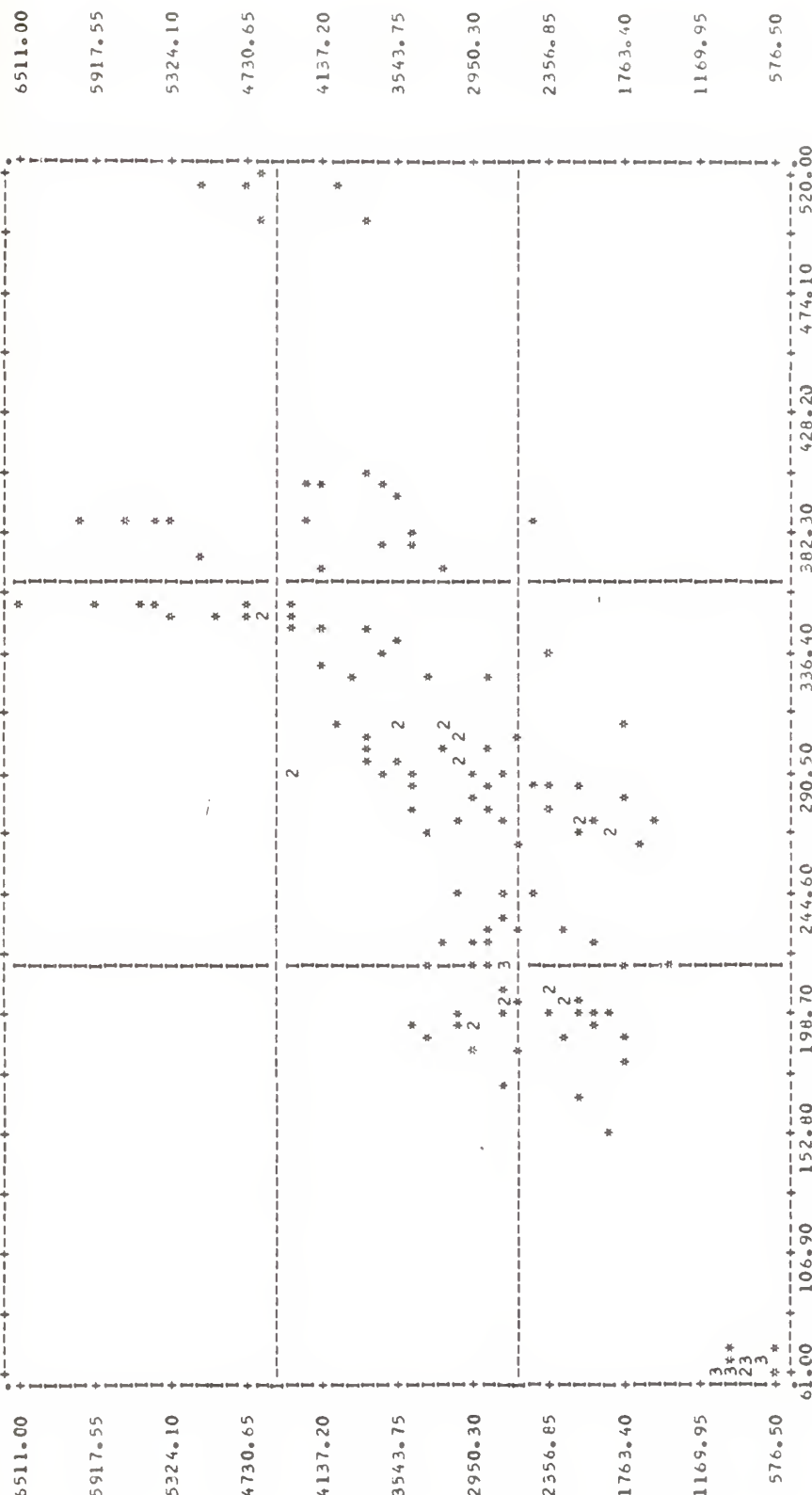
WORK CENTER SUPERVISOR _____

DIVISION OFFICER _____

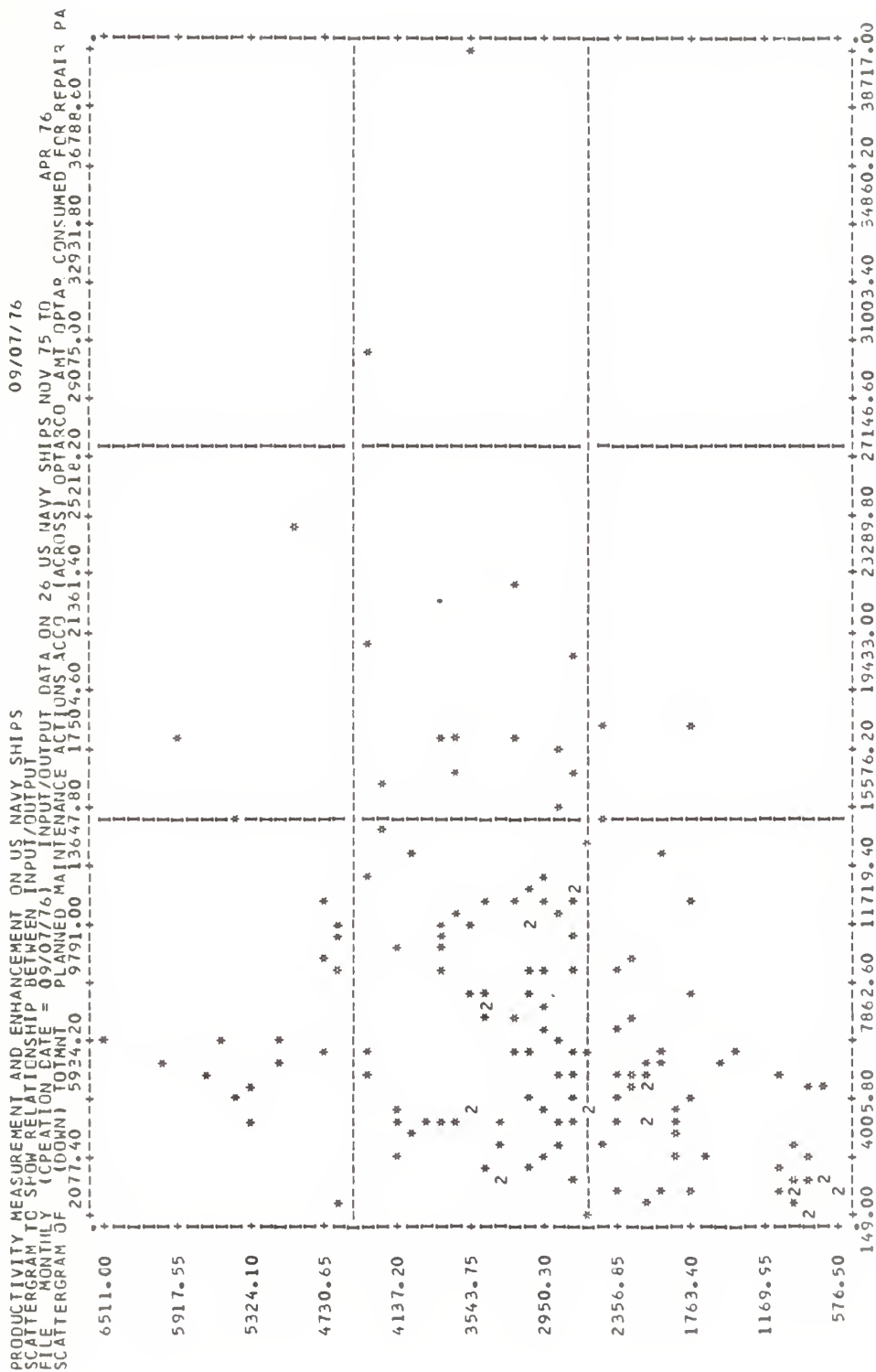
09/07/76

PRODUCTIVITY MEASUREMENT AND ENHANCEMENT ON US NAVY SHIPS

SCATTERGRAM TO SHOW RELATIONSHIP BETWEEN INPUT/OUTPUT DATA ON 26 US NAVY SHIPS NOV 75 TO APR 76
FILE MONTHLY (CREATION CASE = 09/07/76) INPUT/OUTPUT DATA ON 26 US NAVY SHIPS NOV 75 TO APR 76
SCATTERGRAM OF 83.95 (DOWN) TOTIME 129.85 175.75 221.65 267.55 313.45 359.35 405.25 451.15 491.05
PLANNED MAINTENANCE ACTIONS ACCO (ACROSS) MENASS AVERAGE NUMBER MEN ASSIGNED



This scattergram displays planned maintenance actions accomplished on the y-axis and average number of men assigned on the x-axis. The plot of the data points roughly in a straight line suggests that there is a strong relationship between the number of maintenance actions accomplished and the average number of men assigned. The data points for the ATF's (Fleet Tugs) can be seen clustered in the lower left corner of the scattergram. The data points for the LPH (Amphibious Assault Ship) can be seen clustered along the right hand margin of the scattergram.



This scattergram displays planned maintenance actions accomplished on the y-axis and the amount of OPTAR consumed for repair parts on the x-axis. The plot of the data does not fall in a distinct pattern. This suggests that there is little relationship between the number of planned maintenance actions accomplished and the amount of OPTAR consumed for repair parts.

182

ANOVA TABLE FOR MODEL IN Y=A+BX FORM FUNCTION USING INPUT/OUTPUT DATA ON 26 SHIPS

FILE PRODUCTION(CREATION DATE = 09/07/76)

***** MULTIPLE REGRESSION ***** VARIABLE LIST 1
REGRESSION LIST 1

DEPENDENT VARIABLE.. TOTMNT PLANNED MAINTENANCE ACTIONS ACCOMPLISHED

VARIABLE(S) ENTERED ON STEP NUMBER 1.. MENASS AVERAGE NUMBER OF MEN ASSIGNED

MULTIPLE R 0.87022 ANALYSIS OF VARIANCE OF SUM OF SQUARES MEAN SQUARE F
R SQUARE 0.75728 REGRESSION 1. 27528780.32928 74.88100
ADJUSTED R SQUARE 0.75728 RESIDUAL 24. 8823209.07119
STANDARD ERROR 606.32806

----- VARIABLES IN THE EQUATION ----- VARIABLES NOT IN THE EQUATION -----

VARIABLE	8	BETA	STD ERROR 8	F	VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
MENASS	9.88496	0.87022	1.14232	74.881	OPTARCO	0.05466	0.09790	0.77872	0.223
(CONSTANT)	412.69757								

***** ENTERED ON STEP NUMBER 2.. OPTARCO AMT OF OPTAR CONSUMED FOR REPAIR PARTS *****

MULTIPLE R 0.87156 ANALYSIS OF VARIANCE OF SUM OF SQUARES MEAN SQUARE F
R SQUARE 0.75961 REGRESSION 2. 27613349.33565 36.33901
ADJUSTED R SQUARE 0.74959 RESIDUAL 23. 8738640.06483
STANDARD ERROR 616.35344

----- VARIABLES IN THE EQUATION ----- VARIABLES NOT IN THE EQUATION -----

VARIABLE	8	BETA	STD ERROR 8	F	VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
MENASS	9.59250	0.84451	1.31598	53.137					
OPTARCO	0.01458	0.05466	0.03091	0.223					
(CONSTANT)	389.64926								

MAXIMUM STEP REACHED

CORRELATION COEFFICIENTS

A VALUE OF 99.00000 IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED.

TOTMNT	MENASS	OPTARCO	VARIABLE	MEAN	STANDARD DEV	CASES
1.00000	0.87022	0.45192	TOTMNT	3026.7013	1205.8522	26
0.87022	1.00000	0.47041	MENASS	269.4426	106.1270	26
0.45192	0.47041	1.00000	OPTARCO	6876.6821	4519.6441	26

***** ENTERED ON STEP NUMBER 3.. MULTIPLE REGRESSION ***** VARIABLE LIST 1
REGRESSION LIST 1

DEPENDENT VARIABLE.. TOTMNT PLANNED MAINTENANCE ACTIONS ACCOMPLISHED

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	BETA
MENASS	0.87022	0.75728	0.75728	0.87022	0.84451
OPTARCO	0.87156	0.75961	0.00233	0.45192	0.05466
(CONSTANT)					389.64926

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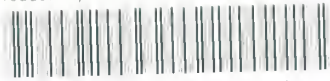
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